POLLEN GATHERING BY HONEY BEES IN LACROSSE COUNTY, WISCONSIN

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ABSTRACT

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By

David W. Severson

Pollen was trapped from honeybee (*Apis mellifera* L.) colonies using the O.A.C. pollen trap at six randomly selected sites, one of which was a commercial apple orchard, within LaCrosse County, Wisconsin during the 1977 blooming season. The corbicular pellets were generally unifloral, which allowed for a separation of the pollen species on a color basis. Once sorted by color, each subsample was weighed to determine the relative percent utilization of each species at each site. Slides, used for species identification, were made of each color using the acetolysis technique. Reference slides from known plant species were made and compared to verify the identities of the bee-gathered pollens.

A study of the major pollen sources within the county revealed that these sources are quite varied throughout the blooming season. Some of the more dominant and long-blooming species were oak, dandelion, fruit trees, clovers, sumac, corn, buckwheat, and composites. Other species such as boxelder, ash, raspberry, and red-osier dogwood are utilized for large amounts of pollen, but have relatively short blooming periods.

The pollen season can be divided into three distinct categories; the early April to late May tree sources, the late May to mid-June shrubs, and the herbaceous species from mid-June through September.

A considerable amount of the pollen collected came from supposedly wind-pollinated species, raising some question as to the true nature of

pollination vector and flower-form relationships. The bees appear to be inclined to forage from any floral source in the apiary vicinity that offers adequate amounts of pollen.

A study of differences in major pollen sources in different apiaries, revealed that the same basic species were utilized at all areas sampled. There were, however, significant differences in the amounts of pollen collected from these species. A noticable exception was buckwheat, which is not routinely in cultivation throughout the county and as such, was only foraged for pollen in apiaries within flight range of this crop.

A study of plants competitive to commercial apple pollination determined that commercial pollination efforts can be severely affected by competitive plants growing in the orchard vicinity. The bulk of the competition was supplied by oak and dandelion.

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INTRODUCTION

Honeybees (Apis mellifera L.), as pollinators, are of considerable value as they account for about 80% of the pollination service to crops. They have likely evolved contemporaneously with the Angiospermous plants and a mutual dependency has developed. However, with the continual increase in human population, a number of problems have arisen with respect to these organisms. To provide adequate and economical food production, large-scale monocultures of commercial crops have been instituted. This has reduced, if not destroyed, the natural sources of nectar and pollen available to the honeybee in many areas. Also, the broad spectrum pesticide control of insects which damage these agricultural crops has destroyed many wild bees and other insects necessary for pollination, placing increasing importance on the honeybee. This has left the honeybee as one of the only pollinators available in sufficient numbers for adequate pollination services. The continual replacement of open fields of bee forage by cities, roads, and other unsuitable environments has further reduced sources of nectar and pollen. It is suggested that honeybees and many species of wild bees are natural resources of such great significance to human welfare that we must try to ensure that they will survive for future generations to carry on their important work. For successful hive management it has become necessary to know the time of flowering of local bee forage plants and their individual importance to the development of colonies of bees.

During a single foraging trip, honeybees may collect pollen, nectar, or both, with the latter being less frequent. They also restrict the majority of their foraging on a single trip to one plant species. This constancy phenomena provides the basis for this study, allowing for the identification and determination of relative importance of particular plant species in the development of honeybee colonies.

One of the prime objectives of this investigation was the development of phenological charts of plants visited by honeybees in search of pollen at a number of sites in LaCrosse County, Wisconsin. Such an objective included the determination of the major pollen sources and their relative importance in colony development. Also, since resident flora may change significantly within a short geographical range, another of the objectives was to examine the differences between sites within the county. A third objective in this study was to identify major plants in competition with commercial apple (Pyrus malus L.) pollination efforts within the county.

In addition to the objectives stated, the data could be used by beekeepers and others for: (1) locating apiaries for proper pollen supplies, (2) choosing plants for propagation on private land, diverted acres, or park areas, (3) determining the best time of year for trapping pollen for supplemental feeding, (4) determining possible pollen deficiencies in a given area, (5) the determination of the relationship of pollen flows to bee management, (6) the determination of plants competitive to crop pollination, (7) and the timing of spraying of crops to prevent poisoning of pollen-collecting bees.

LITERATURE REVIEW

Purpose and Procedure of Pollen Collection

Honeybees collect pollen, which serves as a source of protein in their diet. Eckert (1942) found that an average colony collected about 125 pounds of pollen per year. Of this enormous amount of pollen collected, very little is actually stored for future use. Honeybees use the protein portion of the pollen to provide structural elements of muscles, glands, and other tissues (Dietz, 1975). It was shown by Haydak (1935) that the weight and nitrogen content of emerging bees is directly influenced by the pollen consumption of the nurse bees and the fluctuation in the pollen income of the hive. He also calculated that 120 milligrams of pollen are required per bee produced. Vansell and Todd (1948) reported that the rearing of a frame of brood required about a frame of pollen. Todd and Bishop (1946) stated that one pound of pollen will raise about 4,540 bees. Thus, with two-hundred-thousand bees reared by a strong colony during a year, forty-four pounds of pollen would be required per season.

Pollens differ considerably in their nutritional value, but so far it has not been shown that honeybees prefer specific kinds of pollen or actually make qualitative selections (Martin, 1975). Campana (1975) found significant differences in brood production efficiencies and diet attractiveness of some pure pollen sources. Percival (1947) felt that pollen collection depends to some extent upon the amount of pollen available per flower-form and that bees would not collect from flowers with scanty pollen. She concluded that any plant offering a fair amount of pollen per flower-form would be worked for pollen, provided that it grew within one-quarter mile of the hive and attained a reasonable density. Levin and Bohart (1955) concluded that some pollens are more attractive than others even when separated from the flower structures, color patterns, and perfumes by which they are normally surrounded. Synge (1947) found that bees showed a preference for one species of pollen over another when the pollens were offered simultaneously within the hive. Doull (1966) showed that pollens of different *Eucalyptus* species and other Australian plants differ in their attractiveness to pollen-collecting bees.

Von Frish (1950) felt that honeybees were quided by odor, color, and shape to flowers. He found that bees could distinguish between different qualities of odors and that they had olfactory reactions to different odors resembling that of man. He showed that bees were able to distinguish solid and broken designs. This would account for much of their ability to be extremely selective in foraging preferences. Leleji (1973) showed that honeybees had a strong preference for different cowpea (*Vigna sinensis*) flowers, apparently due to their color, and visited white flowers more than purple flowers in a ratio of two to one. Free (1970) stated that when bees worked flowers of one color only they became conditioned to it and did not visit flowers of a different color. Butler (1971) showed that the quality that first attracts a scouting bee to investigate an artificial or real flower is its color, but that on approaching the attractive object closely the bee is unlikely to investigate it further unless she is able to smell some perfume coming from it. Waller, Loper, and Berdel (1973) showed that bees could be trained to associate a reward with the odor of ocimene (the major component of alfalfa flower aroma) and would select that aroma when given a choice of aroma sites. They concluded that flower preference was due to flower aroma.

The manner in which pollen is collected by honeybees has been studied by a number of workers (Casteel, 1912; Hodges, 1955; Parker, 1926; and Sladen, 1911). Their results indicate that a number of intricate procedures are involved. The antennae, mouth parts, and regions of the head are cleaned by rubbing these parts with the prothroacic legs. The pollen gathered in this manner is removed by brushes on the inside of the first tarsal joint of the mesothroacic legs. It is then passed to the metathoracic legs by means of pollen brushes on the tibia and the first tarsal segments. The mesothoracic legs also collect pollen from the thorax and carry it to the hind legs. The metathoracic legs gather pollen from the abdomen as well as from the anterior appendages. The pollen is forced upward through the auricle and onto the lateral surface of the tibia into the corbicula or pollen basket. Pollen is held in place by long hairs lining the side and one long hair arising from the center of the corbicula. The pollen collected from the mouth parts is moistened with nectar or honey, which adds consistancy to the corbicular pollets and helps hold them in place.

Collection of Bee-Gathered Pollen

Honeybee-gathered pollens have been studied by many individuals, who have used a variety of collection methods. Several authors have collected corbicular pollen from individual bees at the hive entrance (Betts, 1935; Chaturvedi, 1973; Free, 1963; Free and Williams, 1973; and Hodges, 1952, 1958). However, this method is time-consuming and impractical for long-term studies. A number of traps have been developed to collect pollen pellets from the legs of honeybees as they enter the hive (Farrar, 1934; Kauffeld, 1973; Killion, 1945; Nye, 1959; Schaufer and Farrar, 1946; Smith and Adie, 1963; and Todd and Bishop, 1940). These traps may vary greatly in appearance, but all have two basic elements; a grid through which pollen-carrying bees must crawl, removing the pollen pellets in the process, and a container to store these pellets. The Ontario Agricultural College (O.A.C.) pollen trap, as designed by Smith and Adie (1963), was selected for this investigation. Its main advantages are that it is more protective of trapped pollen than most traps and it allows air to circulate around the pollen, thus reducing moisture accumulation and mold problems. A major disadvantage is that debris from the hive also falls through the grid system and accumulates in the pollen sample.

Identification of Bee-Gathered Pollen

Identification of plant species by individual pollen grains is a relatively new study and reliable local keys are unavailable. A few general keys have been developed, however, that aid in identification of some species (Erdtman, 1943, 1966; Faegri and Iverson, 1964; Kapp, 1969; McAndrews, Berti, and Norris, 1973; and Wodehouse, 1965). Since individual plant pollens have characteristic colors, it is possible to separate samples of bee-gathered pollens on this basis with a high degree of accuracy. Reiter (1947) gave ten general classes of color and one-hundred distinct hues for one-hundred and forty-six specimens examined over two seasons in the New York Metropolitan district. He also compared the color of anther pollen to that of corbicular pollen. Hodges (1952) made color charts of pollen loads for one-hundred and twenty plant species. For exact confirmation of a particular species, the standard technique is to prepare a slide of the unknown pollen and compare it with slides of pollens obtained directly from known plant species. A number of techniques have been developed for slide preparation, with the acetolysis process described by Erdtman (1969) being the preferred method.

Pollen Gathering Patterns and Phenological Charts

It has been observed since the days of Aristotle that honeybees do not often visit flowers of different species in one foraging flight, but forage consistantly on one species (Betts, 1935). This constancy phenomena has been studied and confirmed by many authors. Free (1960) found that on a single foraging trip most bees kept to one type of behavior. That is, individual bees collected pollen only on some flower visits and nectar, with or without pollen, on others. Betts (1935) analyzed nine-hundred and fifteen pollen loads, of which eighteen were mingled mixtures and seven were segregated mixtures, resulting in a total of only three percent mixtures. He also reported an additional fifteen percent of the loads contained a few different grains. Chaturvedi (1973) examined one-hundred and ninety-two pollen loads collected in Banthra, Lucknow, India and found only six that were bifloral. He found no loads that contained more than two species. Sharma (1970) examined twenty-seven pollen loads from Kangra Valley, India and found only one which was multifloral. Free (1963) showed that constancy from day to day was less than the constancy within individual foraging trips and that the proportion of bees collecting the original pollen decreased with each successive day of foraging. He also found that the most common pollen tended to be the most constant. Brown (1967) and Butler (1941) determined that honeybees rarely visit the flowers of more than one species of plant on a single foraging trip.

Differences in pollen collection found in hives in different locations is quite predictable. It has been shown, however, that there may be marked differences in collection patterns between hives located in the same apiary. Louveaux (1954) demonstrated that no two colonies gathered the same proportions of pollen by comparing collection patterns of five hives. Maurizio (1953), Synge (1947), and Todd and Bishop (1940) all reported similar findings.

Knowledge of the blooming periods of pollen and honey plants for a given area can be very important to a beekeeper for such practices as installation of package bees, division of colonies, addition of honey supers, removal of honey to avoid unfavorable color or tasting honey, or protection of hives from pesticide poisoning. Parker (1926) listed a chart for pollen and nectar collection from sixty-one species at Ames, Iowa. Synge (1947) found that of approximately one-hundred plant species foraged for pollen at Rothamsted, England during 1946, eighty percent of the total pollen collected could be classified into three groups: legumes (54%), rosaceous trees and shrubs (15%), and forest trees (11%). Hodges (1958) developed a calendar of one-hundred and five bee plants at Ashtead, Surrey, England from 1940 to 1957. Vansell and Todd (1948) studied pollen gathering in thirty-nine western localities and listed thirty-two of the best pollen sources found. They also found some areas to be deficient in supplying necessary nutrients, in the form of adequate forage plants, for colony survival. Mitchener (1948) compiled a list of the blooming dates of pollen and nectar plants at Winnipeg, Manitoba, Canada over a twenty-six year period. Brown (1967), working in Mississippi and Alabama, felt that the pollen year could be divided into three major subdivisions: spring from February to May with many species blooming, summer from June to September with wild grasses (Graminae), sorghum (*Sorghum halepense*), amaranths (Amaranthaceae), and goatweed (*Croton capitatus*) predominating, fall from September to November with composites predominating. Pollen sources in Wisconsin were studied by Knee and Moeller (1967). They determined that corn, red clover (*Trifolium pratense*), white clover (*Trifolium repens*), sweet clover (*Melilotus* sp.), and mustard (*Brassica* sp.) each accounted for over ten percent of the total pollen available.

Nonjudicious usage of pesticides can be disastrous to the beekeeping industry. All attempts must be made to avoid their use on bee forage during blooming periods. The toxicity of various pesticides to honeybees has been studied extensively (Abdelwahab, Khalil, and Hussein, 1973; Atkins, Anderson, and Greywood, 1970a, 1970b; Clinch, Palmer-Jones, and Forester, 1973; Moffett, 1972; and Schricker and Stephen, 1970). Moeller (1972) fed pollen to hives and trapped pollen from them during the corn tasseling period in an attempt to divert the bees from this pollen source after pesticide applications. As a result of these procedures, corn was almost eliminated as a pollen source and bee mortality was highly reduced.

The presence of brood in a colony is a stimulus for pollen gathering (Free, 1967). He found that the proportion of foragers that collected pollen and the amount of pollen collected increased with the amount of brood present. He also found that the smell of brood and contact with bees tending the brood were each partly responsible for foragers collecting pollen. Access to the brood was found to be an important factor.

Apple Pollination

Problems arise with commercial pollination efforts when the target crop becomes less attractive to foraging honeybees than other plant species in the same area. A knowledge of competitive species can be of assistance in assessing the effectiveness of the pollination efforts. Apple flowers need pollination before they set fruit. Free and Williams (1974) studied pollination of self-fertile apple trees and found that bees and other pollinating insects substantially increased pollen transfer on all varieties used. It was felt that the amount of pollen transferred without insects was adequate for a good fruit set, although they may play an important role in pollinating self-compatible varieties in those flowering seasons when there is little wind or when the ovule viablility diminishes so rapidly that early pollination is desirable. Rom (1970) stated that apple trees carry a tremendous excess of blooms, only five to ten percent of which need to set fruit to provide an adequate harvest. He further stated that a five percent fruit set is equivalent to fifty-five-thousand pollinated flowers per acre. With self-incompatible varieties suitable vectors must be present for pollen transfer and with the continual degradation of suitable habitat for wild insect pollinators, honeybees must carry an increased proportion of this process. One honeybee will visit seven-hundred flowers while making eight foraging trips per day. Apple flowers must compete with other plant species in the immediate vicinity if adequate pollination is to be procured. It has therefore been determined (USDA, 1968) that two strong hives of honeybees should be sufficient to pollinate a commercial apple crop on each acre of orchard.

In studying competitive effects it has been indicated (Free, 1958) that a higher proportion of bees visit a crop if their colonies are moved to a site which has recently come into flower. Moffett, Rodney, and Shipman (1974) found that honeybees return to the same species of citrus tree when that species is highly attractive. They did not necessarily return to the same tree in solid plantings so cross-pollination was facilitated. Kremer (1949) reported that several other pollens were collected in traps set in orchards to accumulate apple pollen. Johansen (1955) reported that bees placed in the Lodi variety of apples ignored the apples and foraged on balsam-root (Balsamorhiza sagittata L.). When moved to the Rome Beauty variety these same hives foraged solely on the apples for over two days. At this time mustard (Brassica capestris L.) and dandelion (Taraxacum officinale Weber) began competing for bee visits. Olsen (1975) found that apples compete well for bee visits with other plants which bloom at the same period. Apple pollen intake from three commercial orchards varied from 25.0% to 60.5%. Major competitors were willow (Salix sp.), yellow rocket (Barbarea vulgaris R.Br.), dandelion, and honeysuckle (Lonicera sp.). Minor competitors were horse chestnut (Aesculus hippocastanum L.) and pine (Pinus sp.).

METHODS AND MATERIALS

Collection of Bee-Gathered Pollen

Bee-gathered pollen was trapped twice a week at five sites in La-Crosse County, Wisconsin (Fig. 1) from April 13, 1977 until September [illegible], 1977. Pollen was also trapped from May 4, 1977 to May 7, 1977 from colonies placed in a commercial apple orchard.

Site A was two colonies in the apiary of Ron Pappenfuss. It is located in the southern end of the county in Briedel Coulee. This coulee is oriented in a north-south direction, with the apiary being located towards its northern end. The site is primarily associated with forest vegetation, the dominant vegetation including a pine plantation along the west side of the coulee and numerous birch (Betula papyrifera L.) and oak (Quercus sp.) trees. The entrance to the coulee consists of [illegible] farmland.

Site B was two colonies in the apiary of Clark VanGalder. It is located in the central portion of the county near Barre Mills. This area contains a wet lowland area to the north and open farmland on all remaining sides. There is a large stand of alfalfa (Medicago sativa L.) and a large area associated with grazing of cattle along the apiary perimeter.

Site C was two colonies located in the apiary of David Severson on the north portion of the county near Mindoro. The apiary is located

METHODS AND MATERIALS

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Site A was two colonies in the apiary of Ron Pappenfuss. It is located in the southern end of the county in Briedel Coulee. This coulee is oriented in a north-south direction, with the apiary being located towards its northern end. The site is primarily associated with forest vegetation, the dominant vegetation including a pine plantation along the west side of the coulee and numerous birch (*Betula papyrifera* L.) and oak (*Quercus* sp.) trees. The entrance to the coulee consists of open farmland.

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Site C was two colonies located in the apiary of David Severson on the north portion of the county near Mindoro. The apiary is located along a small stream with a forested area to the north. The remainder of the area is associated with agriculture, corn and soybeans in particular. There is also a considerable amount of poor quality grazing land along the stream bed. On July, 1977 one of the sample colonies had become queenless, so another colony was used for sample collection after that date.

Site D was two colonies in the apiary of Bob Hoffman on the north portion of the county in Amundson Coulee. This coulee is oriented in a north-south direction with the apiary being located towards its southern end. The apiary is surrounded by forest vegetation with birch being the dominant species to the east side. Numerous tree species can be found to the west. There are limited amounts of agricultual land in the immediate outlying areas. One of the sample colonies became queenless after June 11, 1977 so trapping was terminated on it. A replacement hive was not procurred so results after that date are based on data from only one hive.

Site E was two colonies in the apiary of David Peters in the northwest portion of the county. The area is dominated by forest vegetation with oak being predominant. A large portion of the forage area is a golf course.

Site F was two colonies selected at random from colonies placed in the apple orchard of Douglas Sheffelbine on May 2, 1977. The orchard is located approximately fifteen miles north of LaCrosse. It consists of fifty acres of apple trees of the following varieties: Cortland, Duchess, Dudley, Fireside, Golden Delicious, Harrelson, Honeygold, McIntosh, Northwestern Greening, Prairie Spy, Red Delicious, Reagent, Viking, Wealthy, Wellington, Whitney Crab, and Winesap. This orchard is situated on a hilltop surrounded predominantly by oak and white birch on three sides with open farmland to the west.

The Ontario Agricultural College (O.A.C.) pollen trap was selected for trapping pollen. The trap was placed between the bottom board and

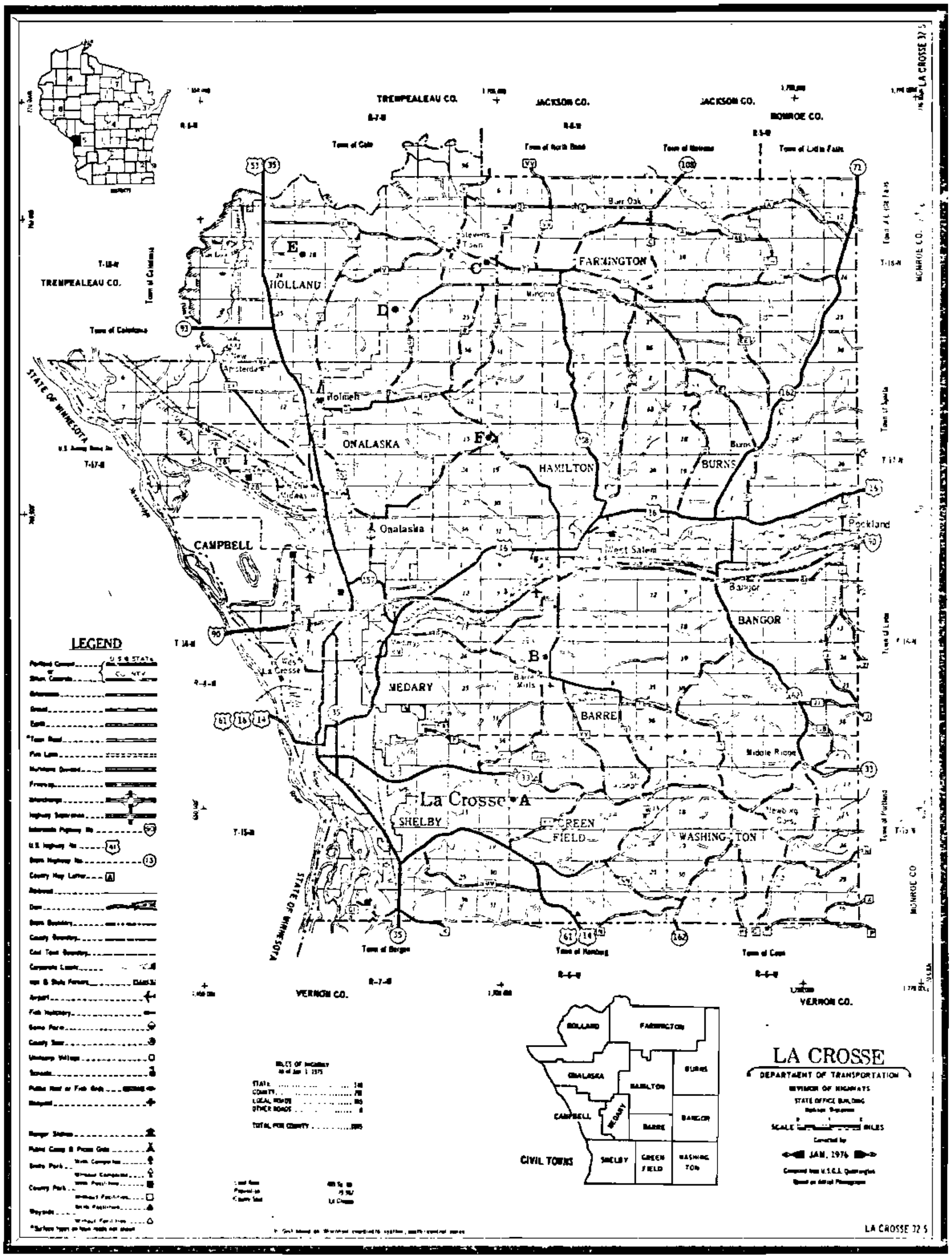


Figure 1: Location of Sample Sites Within LaCrosse County, Wisconsin.

the hive bodies. As the bees entered the hive they were forced to pass through a double layer of five-mesh to the inch hardware screen. This allowed the bees to pass through, but their legs filled with pollen pellets were so wide that the pellets were scraped off as they entered. The pollen pellets fell onto a tray that could be removed from the rear of the hive. This trap allowed the advantage that removing only the five-mesh grid gave the bees free access to the hive. It also had slots which allowed drones to pass through. All samples were labeled by date and location and then frozen for identification in the laboratory later.

Identification of Pollen

In the laboratory the samples were weighed and a subsample was removed for identification. The remainder was stored to be fed to the bees the following spring. The subsamples were weighed and the pellets were sorted by color using a reverse aspirator attached to an air line. The total weight of each color was recorded and the percentage of each color of the total sample was determined. Each color encountered was numbered, with representative pellets being selected from each for microscopic examination. Other subsamples were then compared to these reference colors for identification.

Plants growing in abundance in the vicinity of the six sites were collected and pressed. A set of reference slides was made of pollen from these plants to verify the identity of bee-gathered grains. This was required since comprehensive keys of local pollen grains are not available. A number of texts (Erdtman, 1943, 1966; Faegri and Iverson, 1964; Kapp, 1969; McAndrews, Berti, and Norris, 1973; and Wodehouse, 1965) were utilized for preliminary identification of sample grains.

Plant species that were not collected during the blooming season were obtained through University of Wisconsin-LaCrosse herbarium material. The acetolysis process was used for sample preparation. This process dissolved all organic materials associated externally and internally with the pollen grain and left just the hard outer shell. Drawbacks with this method are that thin-walled pollens become less rigid and may collapse and pollen with opercule tend to lose them. Glycerin jelly was used as the mounting media for the pollen in all cases.

Analysis of Data

After weighing and identification the total weekly yield of each species was calculated at Sites A to E. At Site F the daily yield of each species was calculated. These figures were then converted to percent yields to alleviate differences in the total amount of pollen collected in each sample. Also, a county-wide composite was calculated of all species identified as pollen sources for the blooming season. The percentage of trees, shrubs, and herbs foraged for pollen was determined, along with the percentage of wind-pollinated versus insect-pollinated species utilized.

RESULTS

Site A

Figure 2 shows the weekly percentages for all tree, shrub, and herb pollen identified at Site A. Trees were responsible for almost 100% of the early pollen yield but were not collected subsequent to mid-June. Shrubs provided the predominant pollen source from early May to late June. Herbaceous plant pollen was collected in small amounts in mid-April with a low peak in early May. By the end of June herbs provided the bulk of the pollen sources and continued as such for the remainder of the blooming season.

Figure 3 shows the weekly percentages of wind-pollinated versus insect-pollinated plant species that were foraged for pollen. Wind-pollinated species accounted for a bulk of the early pollen and up to 79.1% of the pollen collected from early July to late August. Insect-pollinated species were minor sources for early spring pollen, but their importance increased as the season advanced to where they provided almost 100% of the sample by mid-June. Insect-pollinated species then decreased in the samples until late July, after which they provided 100% of the weekly totals.

Figure 4 indicates a detailed account of the species identified as major pollen sources for the entire blooming season. Each species is listed as the percent weekly yield. Tree species provided the majority of the pollen samples until late May. Boxelder (*Acer Negundo* L.) provided up to 89.86% of the mid-April pollen, but was not utilized after April. Pollen from trembling aspen (*Populus tremuloides* Michx.) and ash (*Fraxinus* sp.) was also collected in mid-April, with ash providing up to

Figure 2: Plot of the weekly percentages for all trees, shrubs, and herbs identified as pollen sources at Site A.

LEGEND

Trees —·—·—·—

Shrubs —— ——

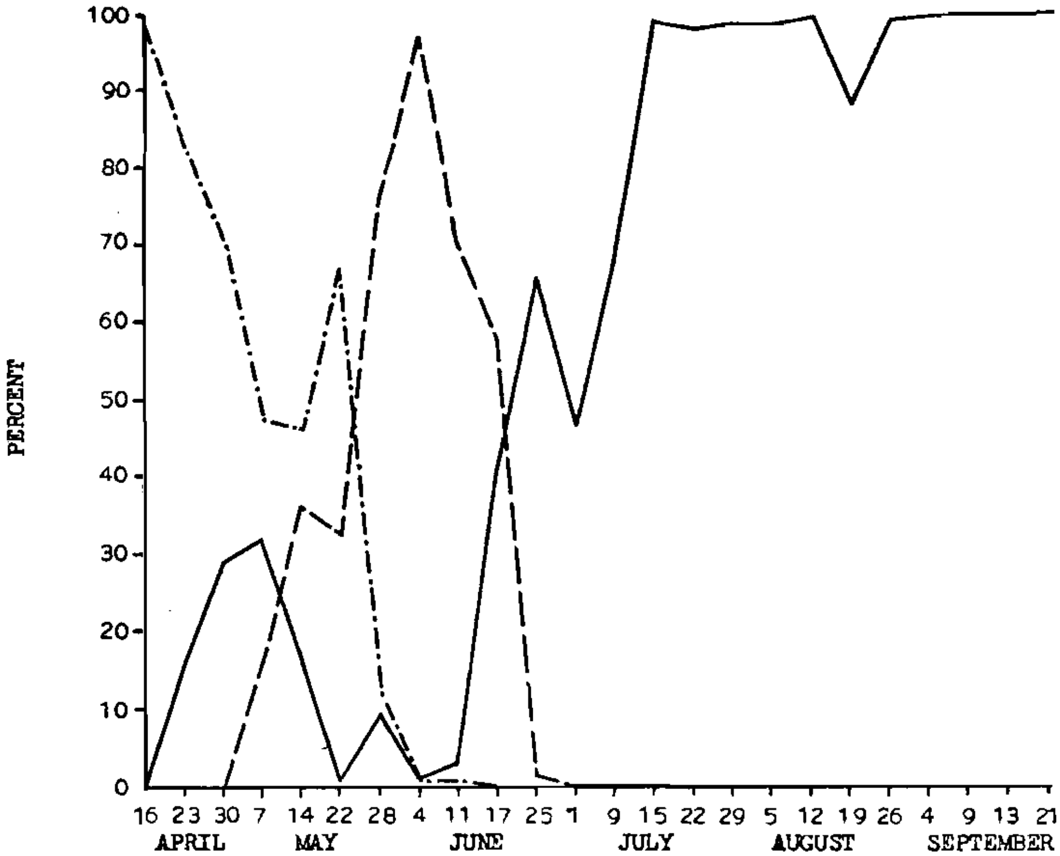
Herbs ————

Figure 3: Plot of the weekly percentages of wind-pollinated versus insect-pollinated species foraged for pollen at Site A.

LEGEND

Wind-pollinated ————

Insect-pollinated —— ——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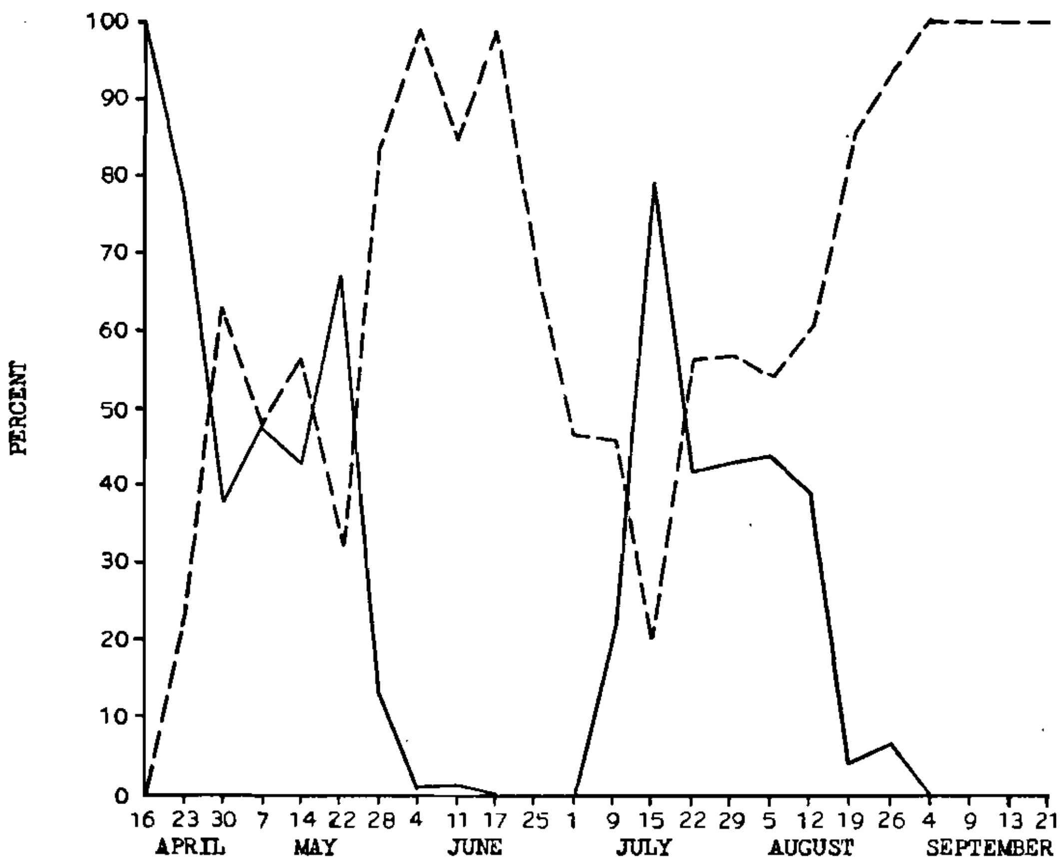
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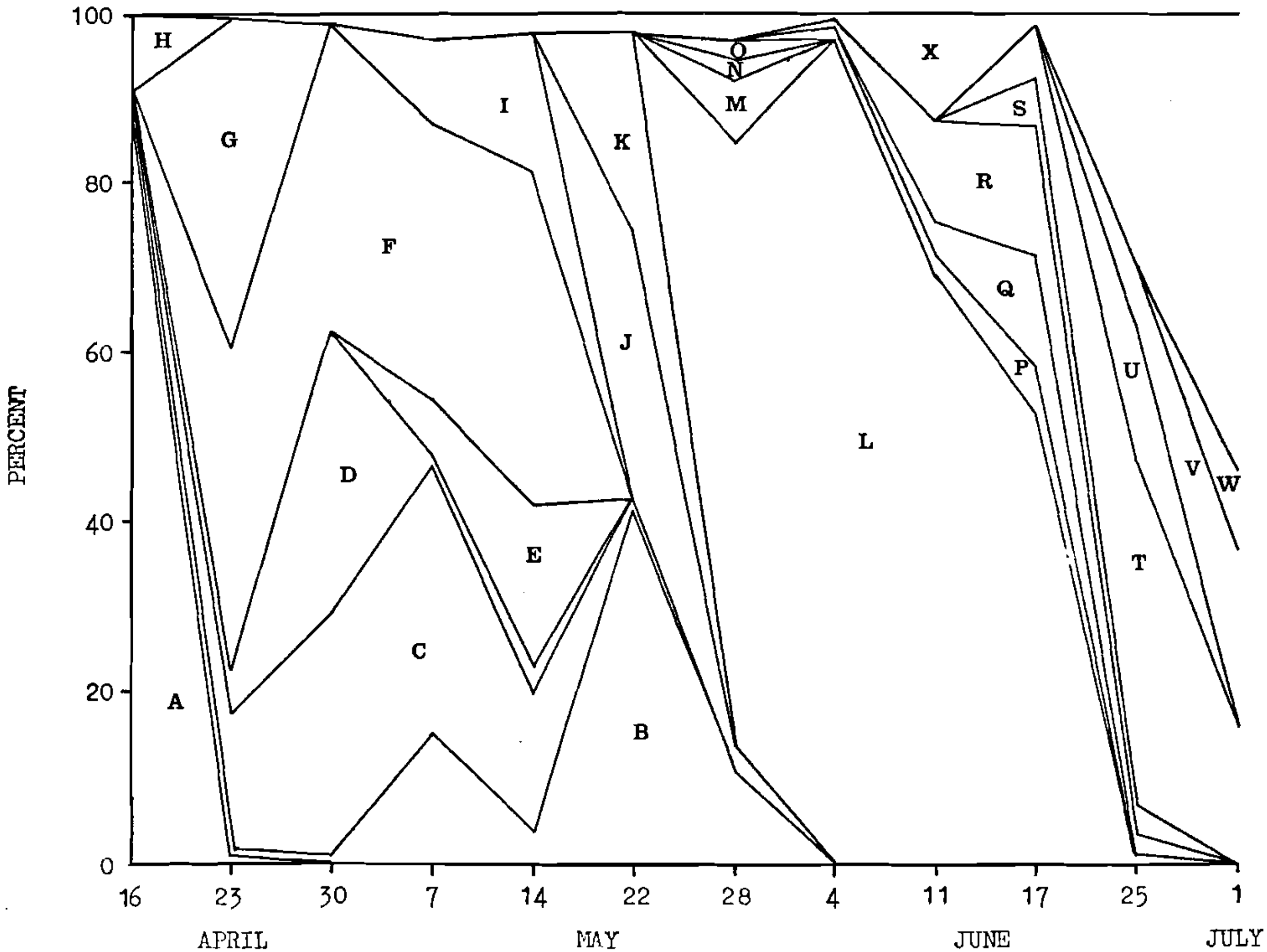
SEPTEMBER

38.97% of the weekly total. Pollen from apple and cherry (Prunus sp.) was collected from late April through May. Oak pollen was collected extensively from late April to late May. Shagbark hickory pollen (Carya ovata K. Koch) was collected in late May. Willow provided pollen from mid-April until late May. Dandelion pollen provided up to 31.55% of the May weekly total and was the only herbaceous pollen collected in abundance until late May. Shrubs were primary pollen sources from late May until late June. Nannyberry (Viburnum lentago L.) and honeysuckle were the earliest shrub sources, providing pollen throughout May. Raspberry (Rubus sp.) provided a large amount of pollen but had a very short blooming period. Pollen from red-osier dogwood (Cornus stolonifera Michx.) and gray dogwood (Cornus racemosa Lam.) was collected in small amounts in June. Sumac (Rhus sp.) provided the bulk of the June pollen with a maximum of 97.18% of a weekly pollen yield. False-solomons seal (Smilacina racemosa L.) and wild grasses were minor herbaceous pollen sources in late May. In mid-June the herbaceous species began to predominate, with legumes providing almost 50% of the pollen yield for the remainder of the season. The major legume was red clover. Birds-foot trefoil (Lotus corniculatus L.) pollen provided up to 40.79% of the late June weekly yield but was absent by late July. Other clovers were identified in the samples, but due to extreme similarity in their pollen grain structure the species could not be differentiated through a microscopic analysis. There were color differences noticed and used as a simple basis for separation. These species have been listed as Legume I, II, III, and IV, with their colors and descriptions being listed in Appendix Table 2. These species probably include white clover, alsike clover (Trifolium hybridum L.), white sweet clover (Melilotus alba

Figure 4: Plot of the percent weekly yield of the species identified as major pollen sources for the entire blooming season at Site A.

LEGEND

A - boxelder
B - willow sp.
C - dandelion
D - cherry & apple sp.
E - nannyberry
F - oak sp.
G - ash sp.
H - trembling aspen
I - honeysuckle sp.
J - raspberry sp.
K - shagbark hickory
L - sumac sp.
M - false-solomons seal
N - red-osier dogwood
O - grass sp.
P - gray dogwood
Q - clover (legume II)
R - clover (legume I)
S - mustard sp.
T - birds-foot trefoil
U - clover (legume III)
V - clover (legume IV)
W - red clover
X - unidentified pollens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JULY
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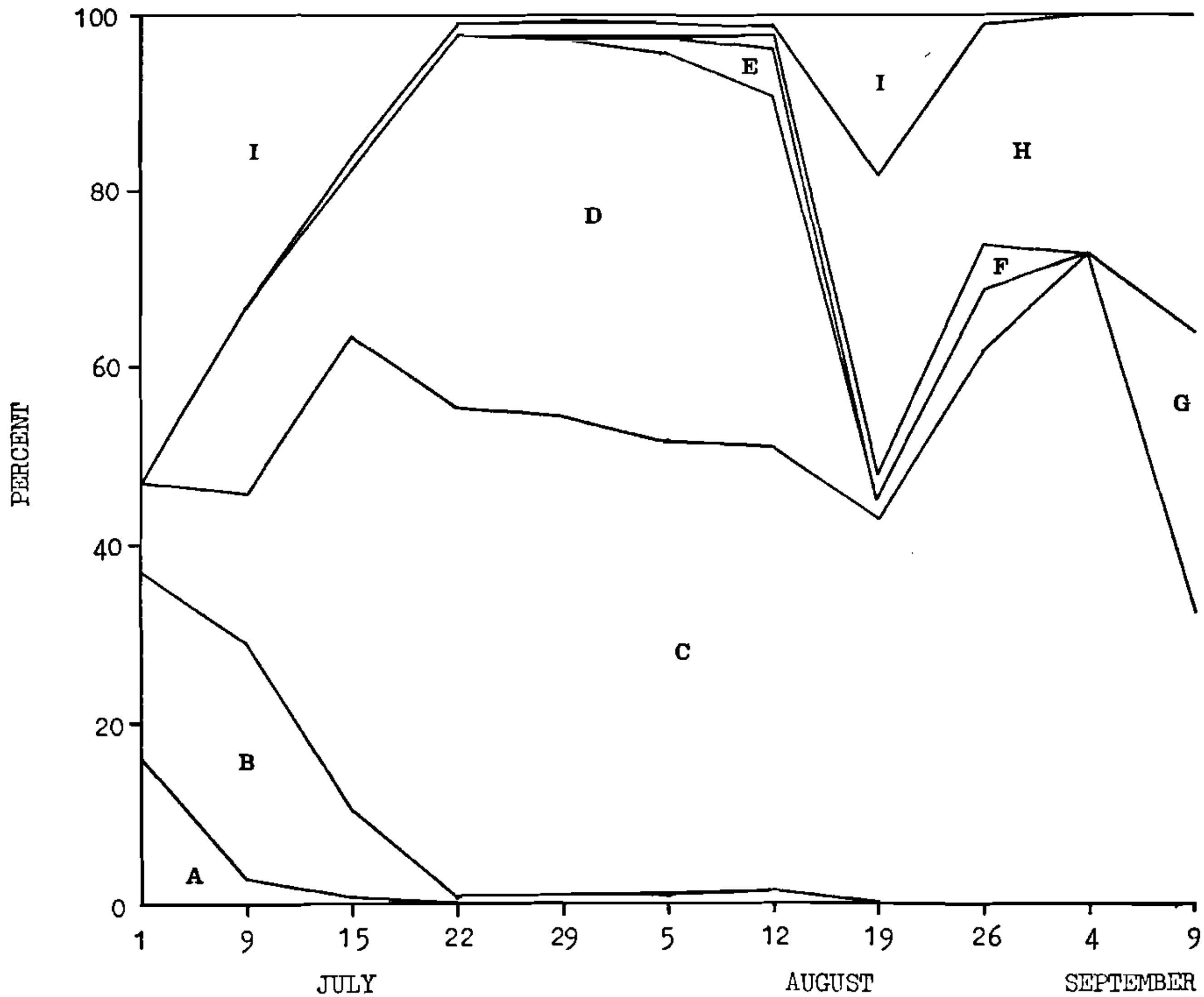
W
X

Figure 4 (continued)

LEGEND

A - birds-foot trefoil
B - clover (legume IV)
C - red clover
D - corn
E - touch-me-not sp.
F - ragweed sp.
G - goldenrod sp.
H - composite sp.
I - unidentified pollens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PERCENT
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29
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12
19
26
4
9
JULY
AUGUST
SEPTEMBER

Desr.), and yellow sweet clover (*Melilotus officinalis* Desr.). Small amounts of mustard pollen were collected during mid-June. From early July until early September an abundance of corn pollen was collected. It provided almost 50% of the weekly yield of pollen for four weeks during that time. Small amounts of pollen from touch-me-not (*Impatiens* sp.) were collected from late July until early September. Composites (Compositae) provided a major source of pollen from August through the remainder of the season. Species that were identified as pollen sources were ragweed (*Ambrosia* sp.) and goldenrod (*Solidago* sp.).

Site B

Figure 5 shows the weekly percentages for all tree, shrub, and herb pollen identified at Site B. Trees provided up to 78.72% of the early pollen sources. Sampling began April 23, 1977 at this site so some of the initial sources of pollen were missed. Shrubs were foraged from late May to late June and accounted for 99.68% of the late May weekly pollen samples. Herbaceous species provided in excess of 50% of the early pollen samples but declined to only 0.19% of those collected in late May. Their importance increased from that point to where they were the only pollen source identified throughout the remainder of the season.

Figure 6 shows the weekly percentages of wind-pollinated versus insect-pollinated plant species that were foraged for pollen. Wind-pollinated species were foraged for pollen early, with 68.28% in mid-May being the maximum. They also provided the bulk of the early July to early August pollen samples. The maximum during this period was 95.80% for mid-July. Insect-pollinated species provided up to 73.90% of the

Figure 5: Plot of the weekly percentages for all trees, shrubs, and herbs identified as pollen sources at Site B.

LEGEND

Trees —·—·—·—

Shrubs —— ——

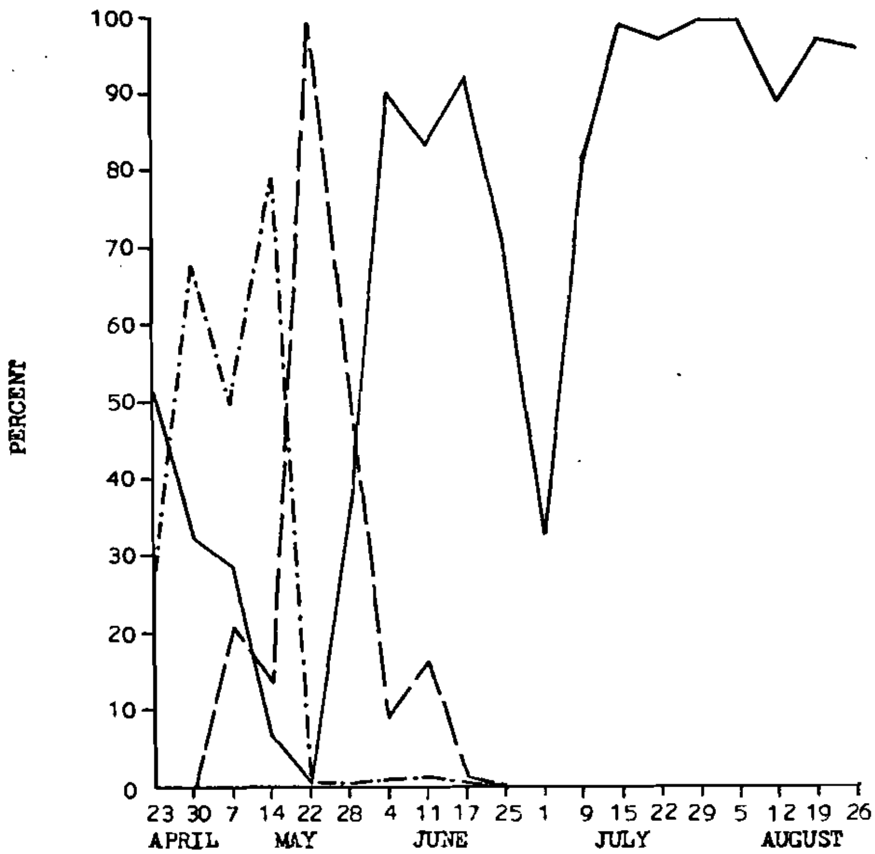
Herbs ————

Figure 6: Plot of the weekly percentages of wind-pollinated versus insect-pollinated species foraged for pollen at Site B.

LEGEND

Wind-pollinated ————

Insect-pollinated —— ——


PERCENT
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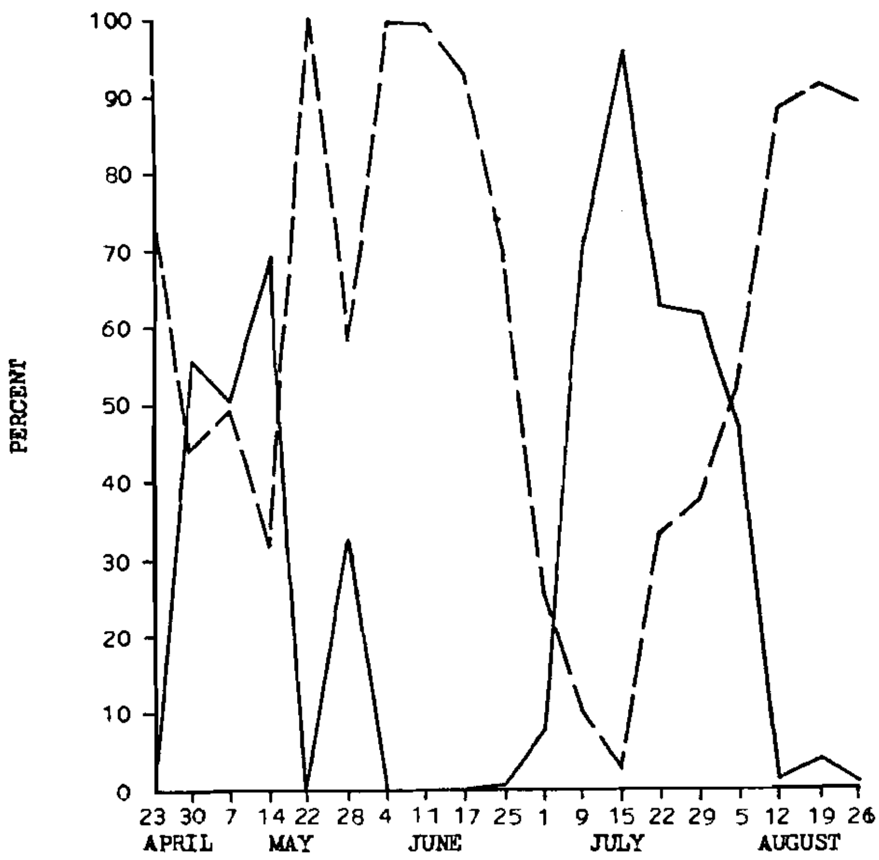
23 30 7 14 22 28 4 11 17 25 1 9 15 22 29 5 12 19 26
APRIL MAY JUNE JULY AUGUST


PERCENT
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23 30 7 14 22 28 4 11 17 25 1 9 15 22 29 5 12 19 26
APRIL MAY JUNE JULY AUGUST

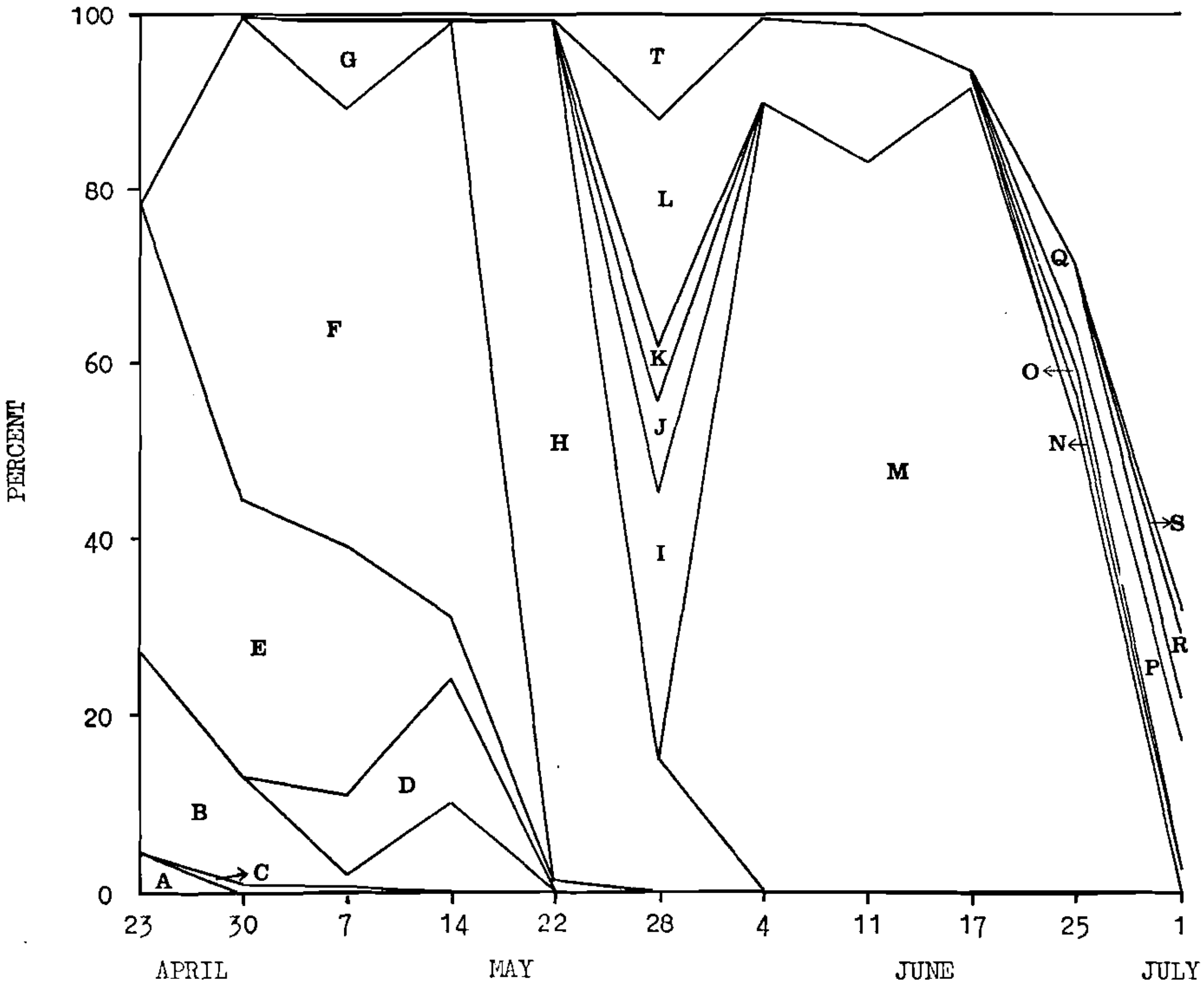
early pollen and peaked in late April to provide 100% of the pollen samples. They declined to only 3.14% of the July pollen samples but then increased to 94.11% by late August.

Figure 7 indicates a detailed account of the species identified as major pollen sources for the entire blooming season. Each species is listed as the percent weekly yield. Tree species provided the majority of the early pollen. Boxelder and willow were minor pollen sources in late May while apple and cherry provided up to 22.88% of the late April to mid-May pollen yield. Oak provided the bulk of the tree pollen and was collected from late April until late May. Dandelion was the only major early herbaceous species collected. Its pollen accounted for a maximum weekly yield of 51.02% in late April and was collected until late May. Shrub pollen was collected from late April to late June. Two early shrub species foraged for pollen were honeysuckle and nannyberry. Grape (Vitis sp.) provided 99.37% of the weekly yield of pollen in late May but its flowering period only lasted three weeks. Up to 26.06% of the early June pollen yield was provided by sumac. Lilac (Syringa vulgaris L.) provided 11.44% of the late May weekly pollen yield. During early June the herbaceous species became the dominant pollen source and after mid-June they provided the only pollen identified. White campion (Lychnis alba Mill.) and mustard pollen was collected in lesser amounts. The legumes (See Appendix Table 2 for descriptions) were collected in abundance throughout the remainder of the season. They provided 91.58% of the mid-June pollen yield. Red clover pollen was collected after late June and provided 62.83% of the yield during late August. Corn pollen was collected in abundance after late June and provided 95.80% of the mid-July yield. An unidentified species

Figure 7: Plot of the percent weekly yield of the species identified as major pollen sources for the entire blooming season at Site B.

<u>LEGEND</u>

A - boxelder
B - cherry & apple sp.
C - willow sp.
D - nannyberry
E - dandelion
F - oak sp.
G - honeysuckle sp.
H - grape sp.
I - grass sp.
J - lilac
K - white campion
L - sumac sp.
M - clover (legume I)
N - mustard sp.
O - clover (legume III)
P - clover (legume IV)
Q - birds-foot trefoil
R - corn
S - red clover
T - unidentified pollens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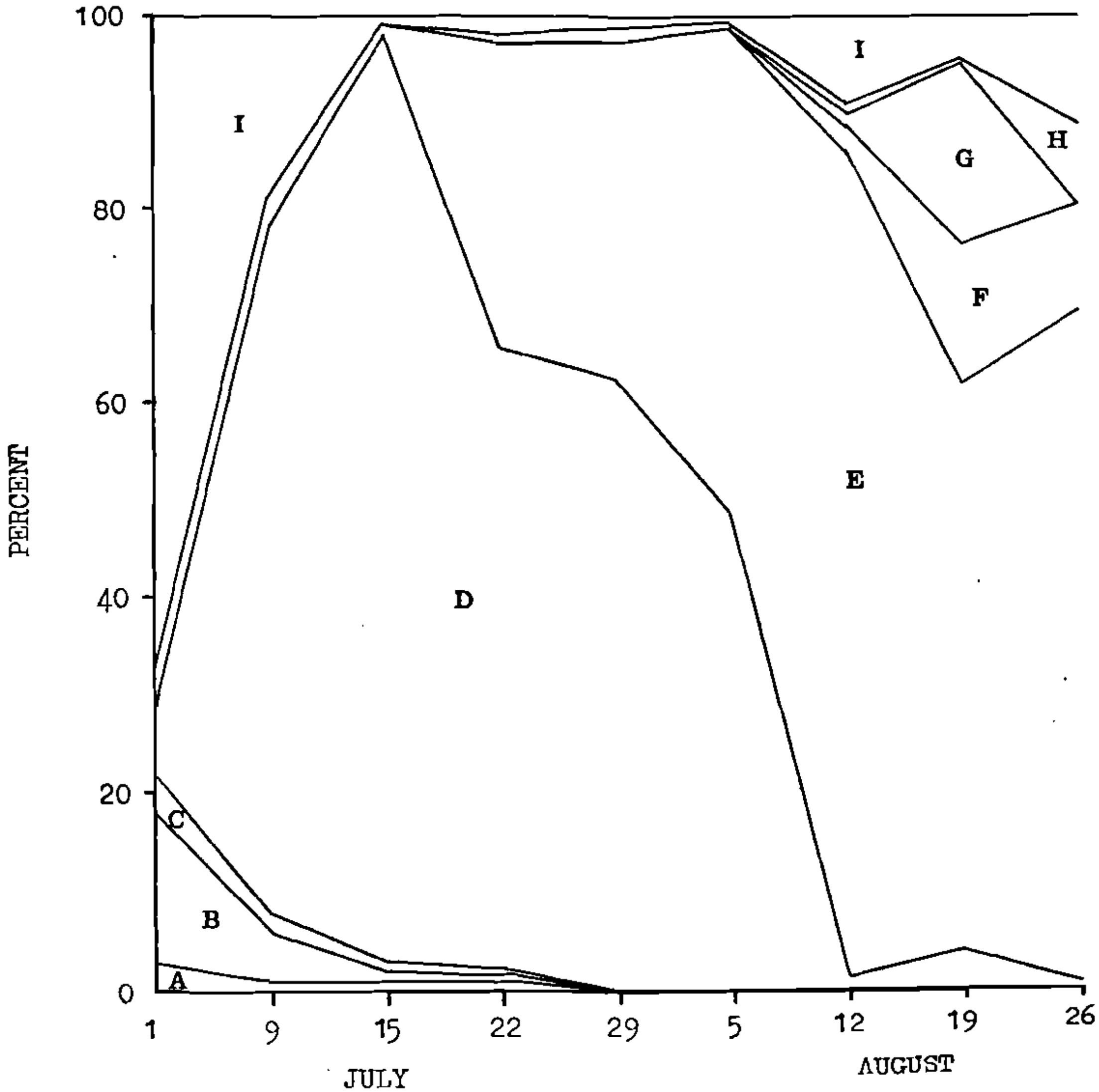
APRIL
MAY
JUNE
JULY

Figure 7 (continued)

LEGEND

A - mustard sp.
B - clover (legume IV)
C - birds-foot trefoil
D - corn
E - red clover
F - touch-me-not sp.
G - ragweed sp.
H - composite sp.
I - unidentified pollens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JULY
AUGUST

(Unknown I) accounted for 67.19% of the early July pollen. The color and description of this grain is listed in Appendix Table 2. Touch-me-not provided up to 13.27% of the total pollen in August. Composite pollen was also collected throughout August, with ragweed providing the largest source of composite pollen. Trapping was terminated at this site at the end of August so information on fall flowers is not available.

Site C

Figure 8 shows the weekly percentages for all tree, shrub, and herb pollen identified at Site C. Sampling began in early May at this site because the trap colonies were started from packaged bees in mid-April. These packages consisted of two pounds of bees with a queen and were obtained from Georgia. As a result the early spring pollen sources were missed. Trees provided the bulk of the May pollen, with shrub pollen beginning in May and reaching a peak in mid-June. A very low percentage of herbaceous species were foraged in May and early June but by mid-June they increased in importance to an almost 100% weekly yield of the pollen for the remainder of the season.

Figure 9 shows the weekly percentages of wind-pollinated versus insect-pollinated plant species that were foraged for pollen. Wind-pollinated species were utilized heavily in May, while none were identified during late June. They were also collected extensively from early July until early September, providing up to 68.37% of the weekly pollen samples. Insect-pollinated species were foraged for pollen in lesser amounts in May but provided 100% of the early June weekly pollen samples. Their collection decreased to 30.44% in early August and then

Figure 8: Plot of the weekly percentages for all trees, shrubs, and herbs identified as pollen sources at Site C.

LEGEND

Trees —·—·—·—

Shrubs —— ——

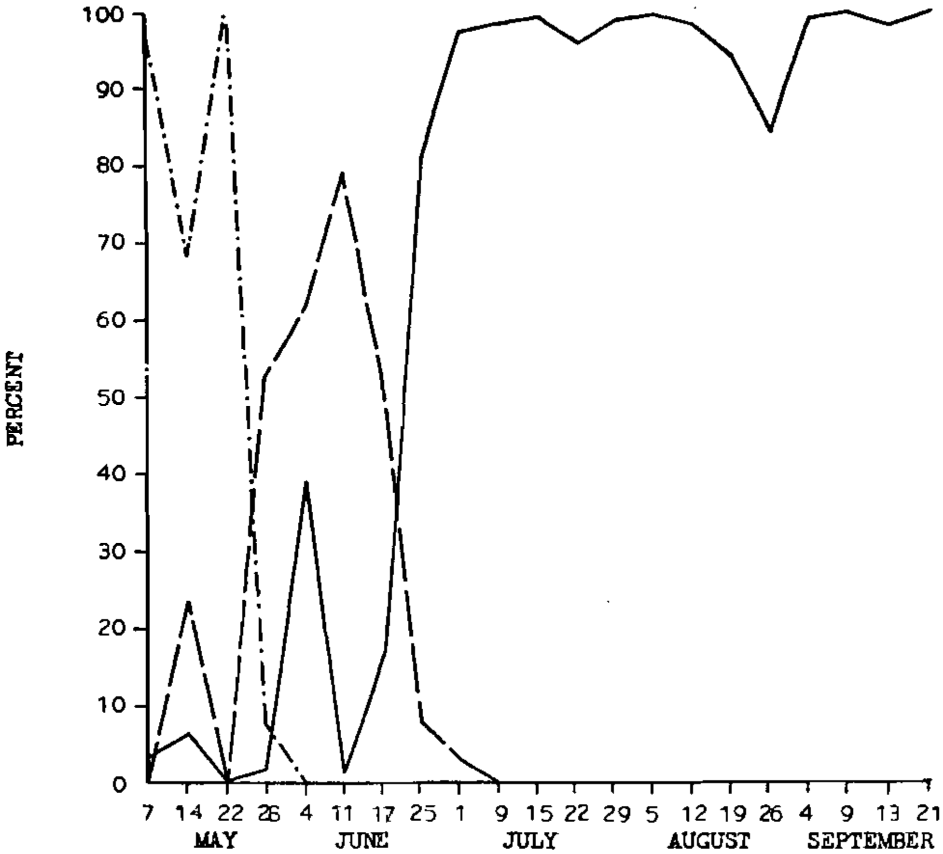
Herbs ————

Figure 9: Plot of the weekly percentages of wind-pollinated versus insect-pollinated species foraged for pollen at Site C.

LEGEND

Wind-pollinated ————

Insect-pollinated —— ——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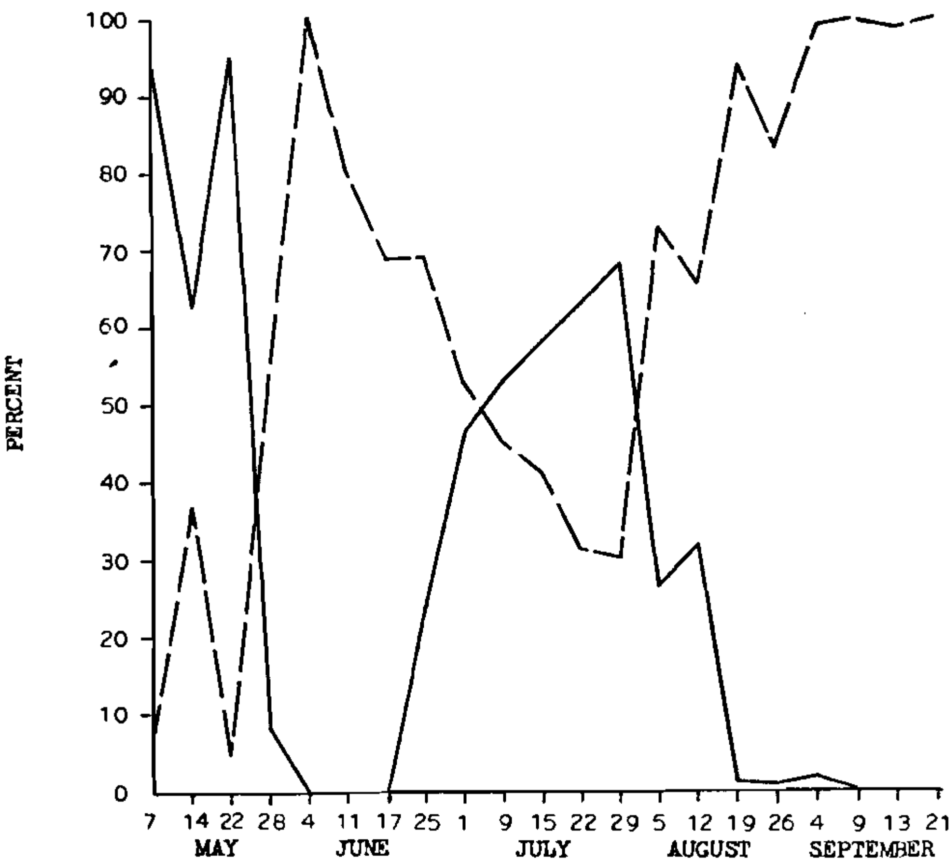
MAY
JUNE
JULY
AUGUST
SEPTEMBER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MAY
JUNE
JULY
AUGUST
SEPTEMBER

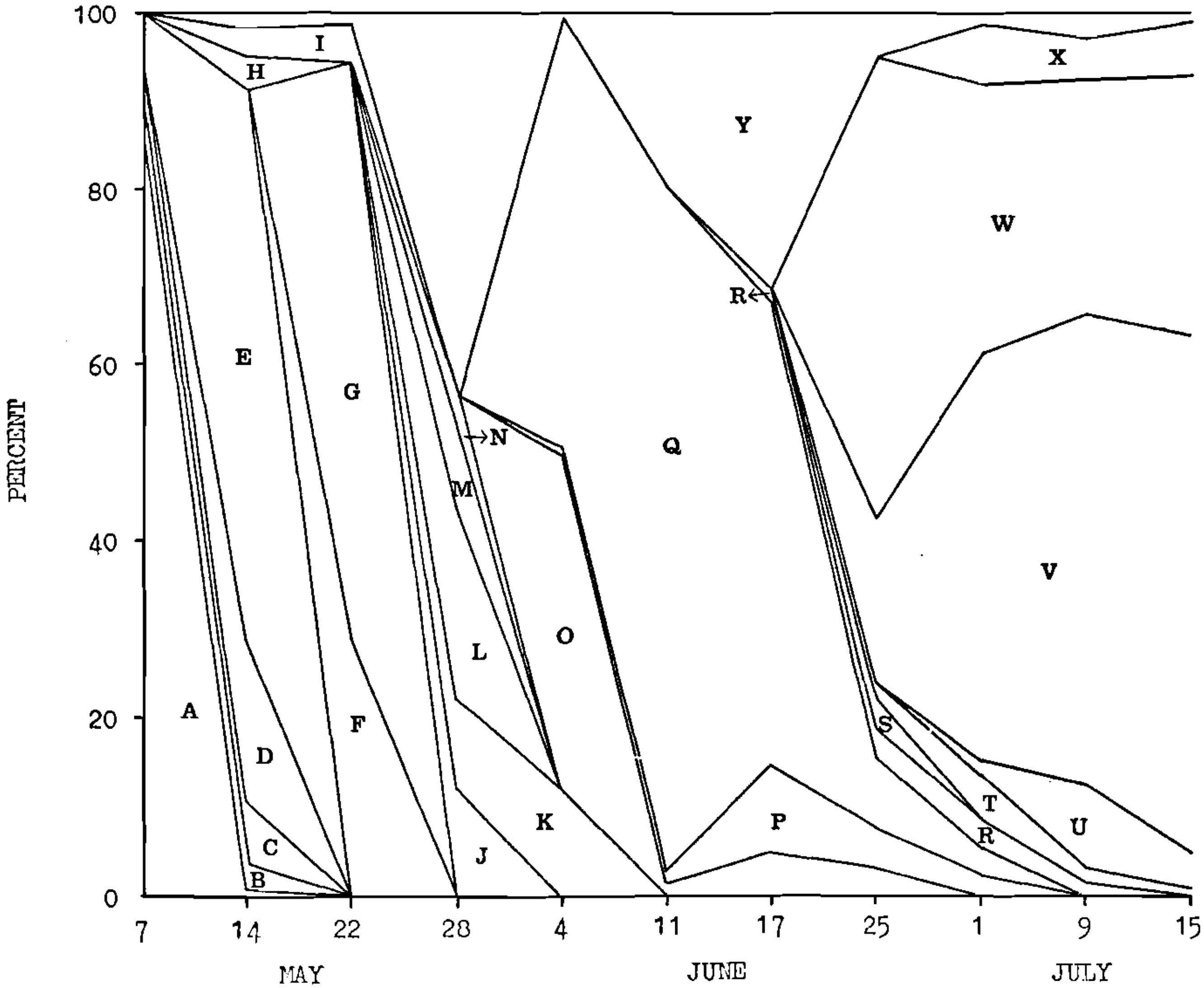
increased to almost 100% of the weekly pollen samples for the remainder of the season.

Figure 10 indicates a detailed account of the species identified as major pollen sources for the entire blooming season. Each species is listed as the percent weekly yield. Tree species provided the bulk of the May pollen. Willow provided up to 86.51% of the early May pollen. Small amounts of apple and cherry pollen were also collected during this time. Oak, black walnut (<u>Juglans nigra</u> L.), and shagbark hickory all provided large quantities of pollen during May, with black locust (<u>Robinia pseudoacacia</u> L.) providing small amounts of pollen during this period. Dandelion was the only early herbaceous pollen source, although it provided only 6.64% of the weekly pollen samples at its maximum. A number of shrub species were utilized as pollen sources from mid-May until early July. Nannyberry and poison-ivy (<u>Rhus radicans</u> L.), blooming in mid-May, were the first shrub species of pollen to be utilized. Pollen from grape, gray dogwood, red-osier dogwood, and lilac was collected in fairly small amounts during late May. Sumac provided the bulk of the shrub pollen and was collected throughout June. The maximum weekly yield from this species was 77.34% in mid-June. Herbaceous species foraged for pollen in June were wild grasses, mustard, and legumes. The herbaceous species predominated in late June and were the only pollen source after early July. Red clover was the major legume and its pollen was collected throughout this period. It provided 69.42% of the final weekly pollen samples. Also observed throughout June and July was the pollen from birds-foot trefoil. A description of all other legume pollen collected is given in Appendix Table 2. The dominant species from late June until late August was corn. It provided up to 68.37% of

Figure 10: Plot of the percent weekly yield of the species identified as major pollen sources for the entire blooming season at Site C.

LEGEND

A - willow sp.
B - cherry & apple sp.
C - dandelion
D - nannyberry
E - oak sp.
F - black walnut
G - shagbark hickory
H - poison-ivy
I - black locust
J - grape sp.
K - gray dogwood
L - red-osier dogwood
M - lilac
N - grass sp.
O - clover (legume I)
P - clover (legume II)
Q - sumac sp.
R - birds-foot trefoil
S - mustard sp.
T - clover (legume IV)
U - red clover
V - corn
W - thistle sp.
X - composite sp.
Y - unidentified pollens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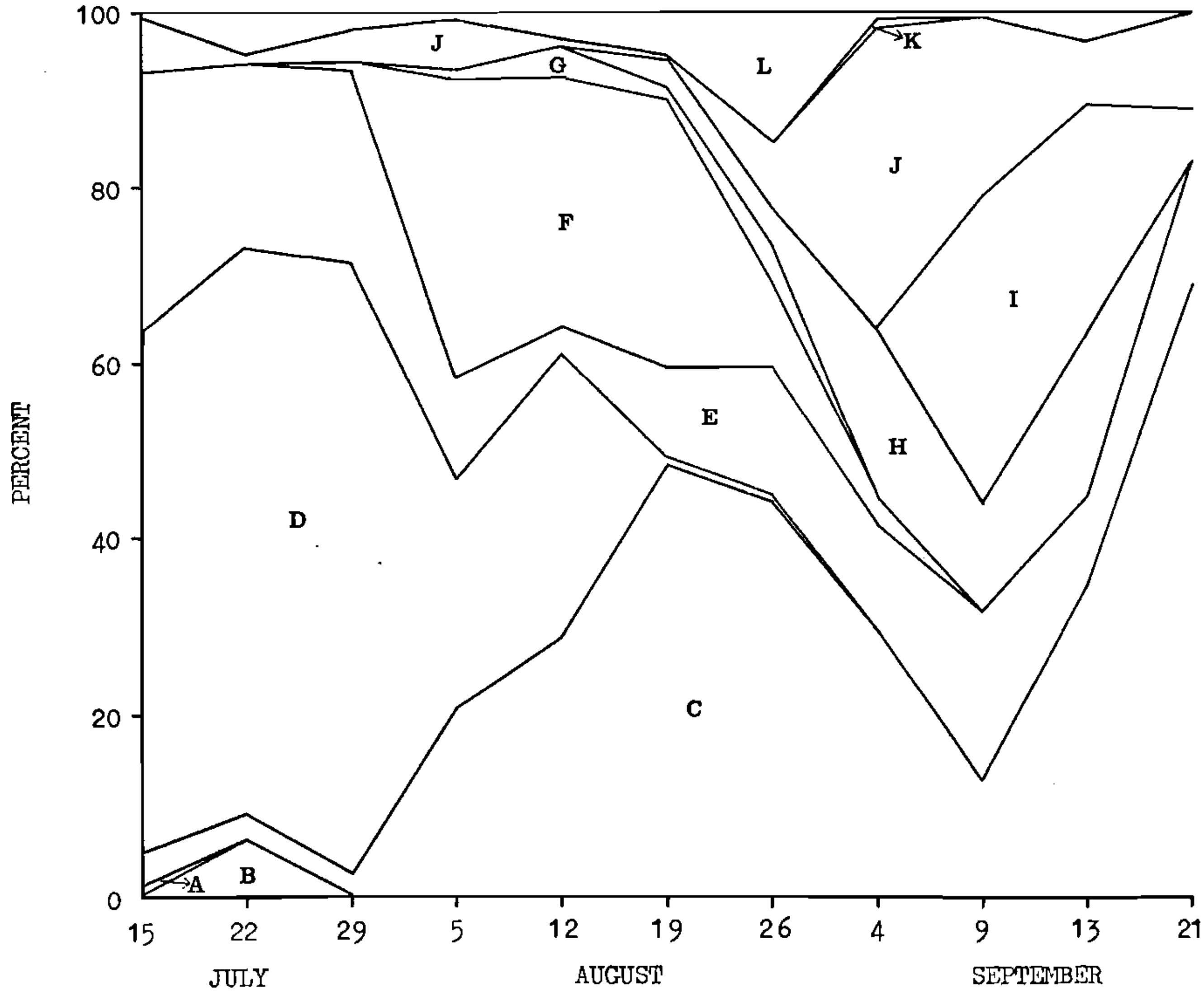
V
W
X
Y

Figure 10 (continued)

LEGEND

A - clover (legume IV)
B - birds-foot trefoil
C - red clover
D - corn
E - thistle sp.
F - ragweed sp.
G - touch-me-not sp.
H - smartweed sp.
I - goldenrod sp.
J - composite sp.
K - sedge sp.
L - unidentified pollens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JULY
AUGUST
SEPTEMBER

the weekly pollen samples. Composites were also a major source of pollen after late June. Thistle (Cirsium sp.) was utilized as a pollen source during this whole period and provided up to 52.78% of the weekly pollen samples. Other composites identified as pollen sources were ragweed and goldenrod. From late August until late September, smartweed (Polygonum sp.) pollen provided up to 19.41% of the weekly samples. Pollen from touch-me-not and Cyperaceae was collected in lesser amounts from early August until early September.

Site D

Figure 11 shows the weekly percentages for all tree, shrub, and herb pollen identified at Site D. Trees accounted for 100% of the mid-April pollen samples but were not found in any samples after late May. Shrubs were utilized from early May until mid-June, providing up to 58.88% of the weekly pollen samples. Pollen from herbaceous species showed peaks of 43.93% in early May and 65.08% in early June. Their importance increased in late June to where they were the only pollen identified for the remainder of the season.

Figure 12 shows the weekly percentages of wind-pollinated versus insect-pollinated plant species that were foraged for pollen. Wind-pollinated species accounted for 100% of the mid-April pollen samples, with varying amounts being collected until late June. They also provided up to 77.88% of the early July to mid-August pollen samples. Insect-pollinated species were utilized from after late April, with a peak of 79.23% being noted. They provided almost 100% of the weekly pollen samples from late May until early July and from early August through the remainder of the season.

Figure 11: Plot of the weekly percentages for all trees, shrubs, and herbs identified as pollen sources at Site D.

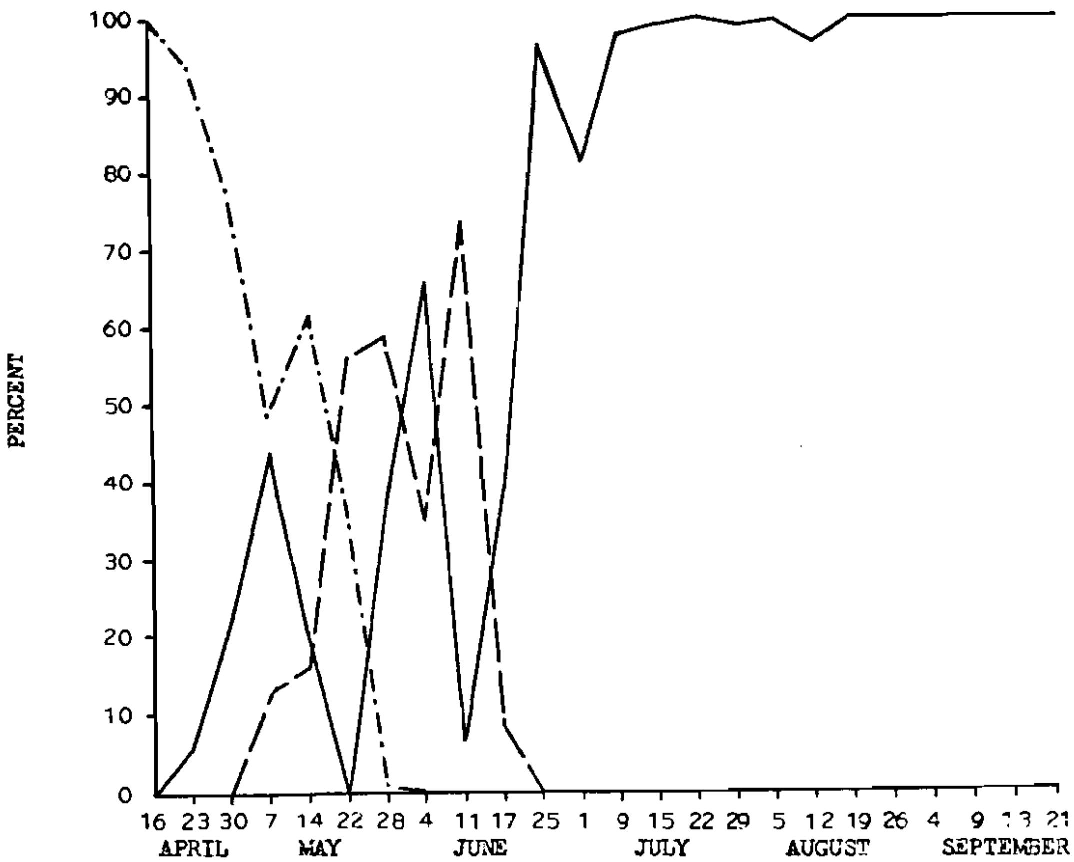
LEGEND

Trees	—·—·—·—
Shrubs	—— ——
Herbs	————

Figure 12: Plot of the weekly percentages of wind-pollinated versus insect-pollinated species foraged for pollen at Site D.

LEGEND

Wind-pollinated	————
Insect-pollinated	—— ——


PERCENT
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16 23 30 7 14 22 28 4 11 17 25 1 9 15 22 29 5 12 19 26 4 9 13 21
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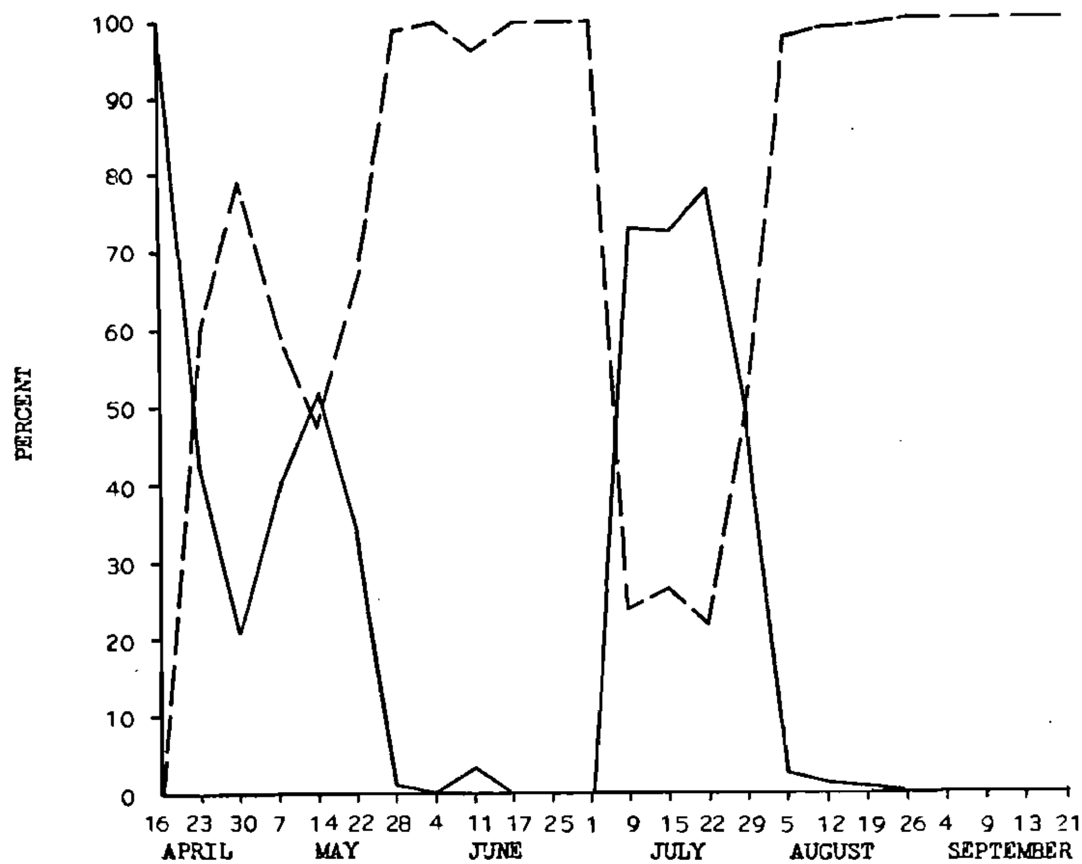
JUNE
JULY
AUGUST
SEPTEMBER


PERCENT
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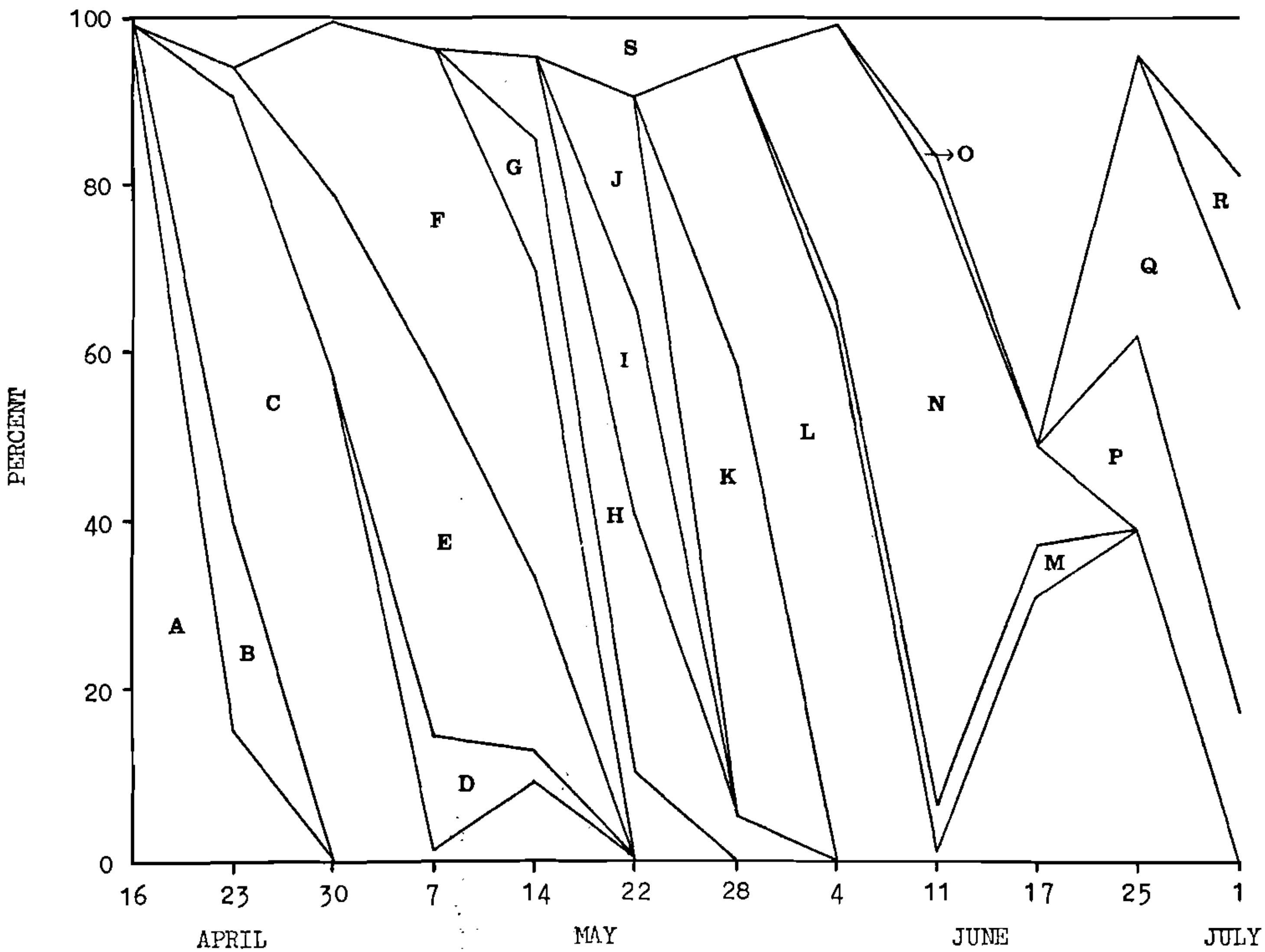
16 23 30 7 14 22 28 4 11 17 25 1 9 15 22 29 5 12 19 26 4 9 13 21
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER

Figure 13 indicates a detailed account of the species identified as major pollen sources for the entire blooming season. Each species is listed as the percent weekly yield. Tree species accounted for the bulk of the pollen samples until late May. Boxelder provided 97.13% of the mid-April pollen samples but was not encountered after April 30. Willow, apple, and cherry were also early pollen sources, with apple and cherry providing up to 57.16% of the weekly pollen samples. Oak provided a major source of pollen from late April until mid-May. Black walnut and shagbark hickory were utilized as pollen sources from mid to late May. Dandelion provided the only major herbaceous pollen early in the season, with a maximum of 43.93% of the weekly pollen samples. Nannyberry provided the first shrub pollen in early May with poison-ivy, raspberry, and red-osier dogwood predominating as pollen sources in late May. Sumac provided up to 73.46% of the June pollen samples. Pollen from herbaceous species was collected from late May throughout the remainder of the season. Herbaceous species provided the only pollen source after late June. An unidentified species (Unknown II) provided up to 38.72% of the mid-June weekly pollen samples. The color and description of this grain is listed in Appendix Table 2. The legumes provided the bulk of the herbaceous pollen sources from late May until early July. Red clover was utilized as a pollen source from the end of June to September. A description of other legume pollen collected is given in Appendix Table 2. Thistle accounted for up to 13.32% of the weekly pollen samples during July. The dominant species during July was corn, which provided up to 77.88% of the weekly pollen samples. From late July until mid-August buckwheat (Fagopyrum esculentum Moench.) provided up to 94.89% of the weekly pollen samples. Composites were the

Figure 13: Plot of the percent weekly yield of the species identified as major pollen sources for the entire blooming season at Site D.

LEGEND

A - boxelder
B - willow sp.
C - cherry & apple sp.
D - nannyberry
E - dandelion
F - oak sp.
G - black walnut
H - poison-ivy
I - raspberry sp.
J - shagbark hickory
K - red-osier dogwood
L - clover (legume I)
M - clover (legume II)
N - sumac sp.
O - grass sp.
P - clover (legume III)
Q - clover (legume IV)
R - red clover
S - unidentified pollens



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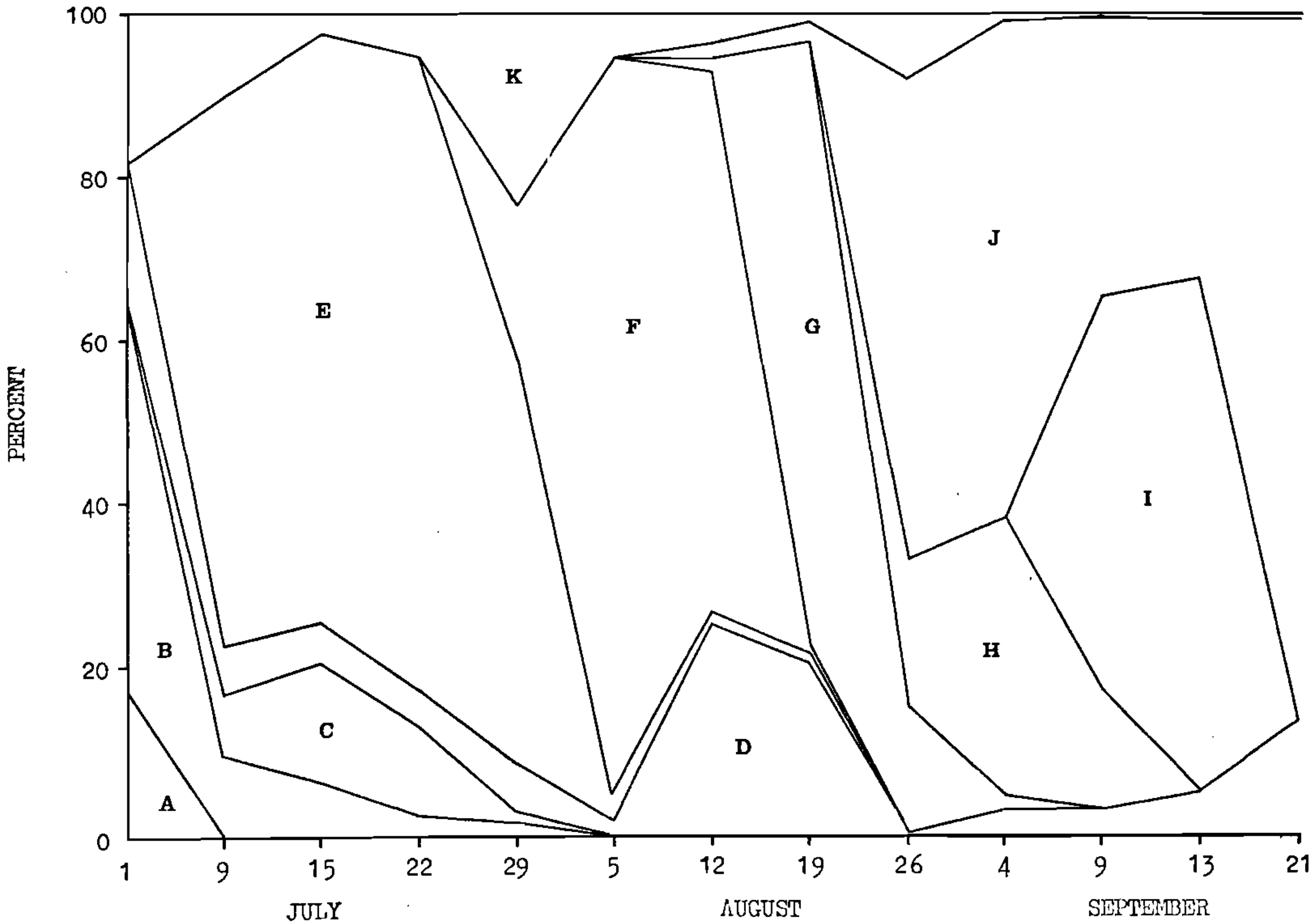
APRIL
MAY
JUNE
JULY

Figure 13 (continued)

LEGEND

A - clover (legume III)
B - clover (legume IV)
C - thistle sp.
D - red clover
E - corn
F - buckwheat

G - ragweed sp.
H - sowthistle sp.
I - goldenrod sp.
J - composite sp.
K - unidentified pollens



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JULY
AUGUST
SEPTEMBER

dominant source of pollen from late August through September. Those identified as pollen sources included ragweed, sowthistle (Sonchus sp.), and goldenrod.

Site E

Figure 14 shows the weekly percentages for all tree, shrub, and herb pollen identified at Site E. Trees accounted for 99.97% of the mid-April pollen but were not found in any pollen samples after late May. Shrubs provided pollen from early May until mid-July with a maximum weekly yield of 66.00%. Herbaceous species accounted for up to 64.10% of the weekly pollen samples in late May and proceeded to provide the only pollen source after early July.

Figure 15 shows the weekly percentages of wind-pollinated versus insect-pollinated plant species that were foraged for pollen. Wind-pollinated species provided 100% of the mid-April and up to 65.68% of the late April pollen. The amount collected, however, declined to zero by early June. Wind-pollinated species also provided up to 79.10% of the late June to mid-August pollen. Insect-pollinated species increased in the pollen samples from zero in mid-April to 99.76% by early June. They then declined to 19.95% in mid-July but increased to provide almost 100% of the pollen by late August.

Figure 16 indicates a detailed account of the species identified as major pollen sources for the entire blooming season. Each species is listed as the percent weekly yield. Tree species provided the bulk of the pollen until late May. Boxelder provided 87.04% of the mid-April pollen with willow, ash, and trembling aspen providing lesser amounts. Pollen from oak, apple, cherry, and willow was collected from late April

Figure 14: Plot of the weekly percentages for all trees, shrubs, and herbs identified as pollen sources at Site E.

LEGEND

Trees —·—·—·—

Shrubs —— ——

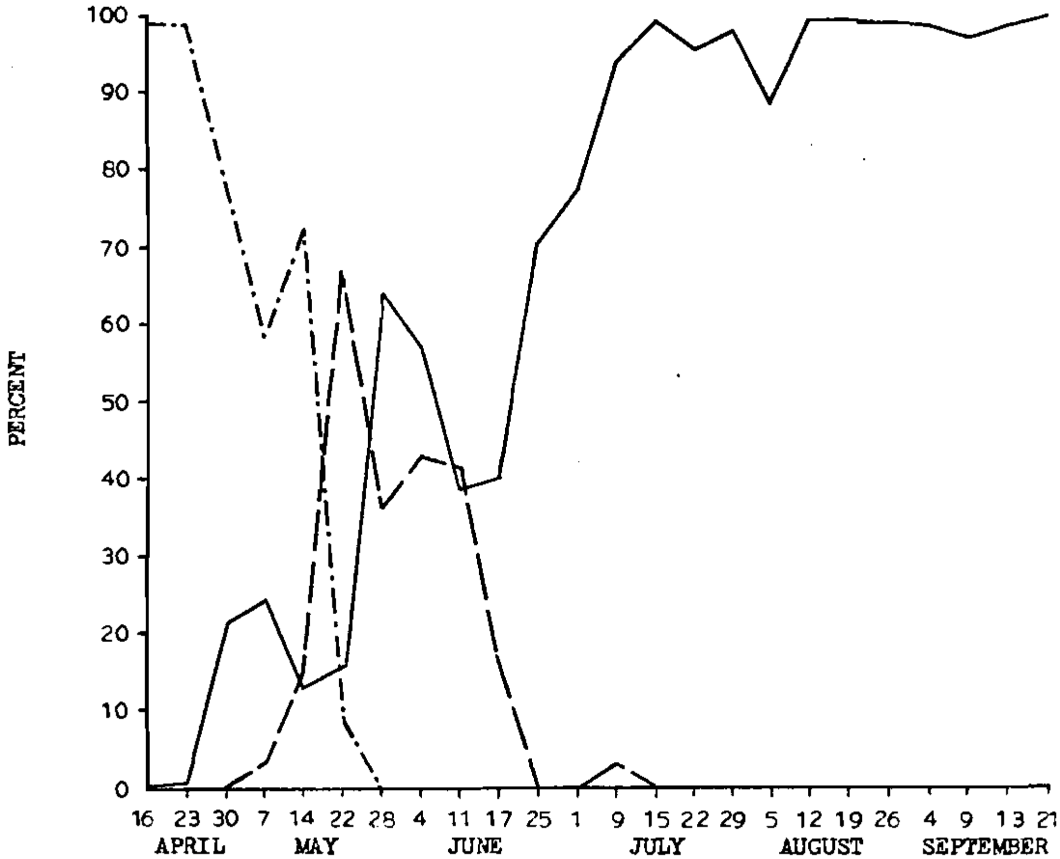
Herbs ————

Figure 15: Plot of the weekly percentages of wind-pollinated versus insect-pollinated species foraged for pollen at Site E.

LEGEND

Wind-pollinated ————

Insect-pollinated —— ——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APRIL
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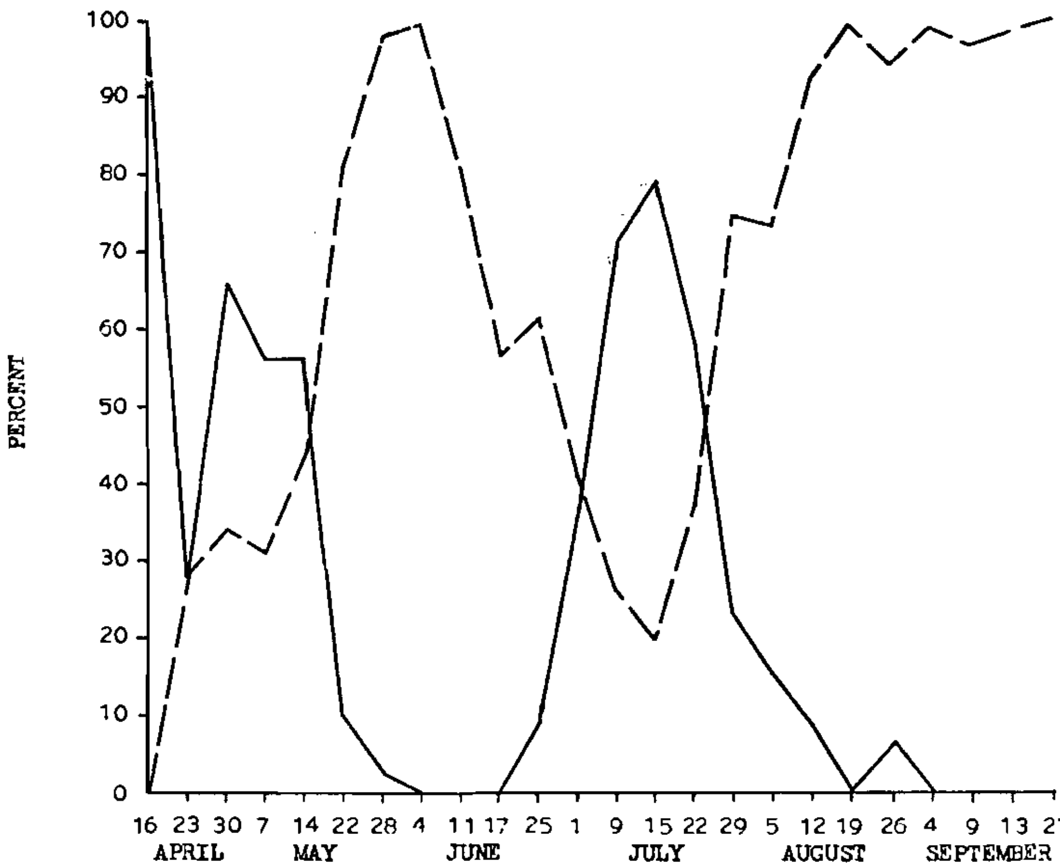
JUNE
JULY
AUGUST
SEPTEMBER


PERCENT
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16 23 30 7 14 22 28 4 11 17 25 1 9 15 22 29 5 12 19 26 4 9 13 21
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER

Figure 16: Plot of the percent weekly yield of the species identified as major pollen sources for the entire blooming season at Site E.

LEGEND

A - boxelder
B - willow sp.
C - cherry & apple sp.
D - nannyberry
E - dandelion
F - oak sp.
G - trembling aspen
H - ash sp.
I - grape sp.
J - raspberry sp.
K - shagbark hickory
L - black locust
M - red-osier dogwood
N - false-solomons seal
O - clover (legume I)
P - grass sp.
Q - clover (legume II)
R - sumac sp.
S - mustard sp.
T - clover (legume IV)
U - corn
V - unidentified pollens

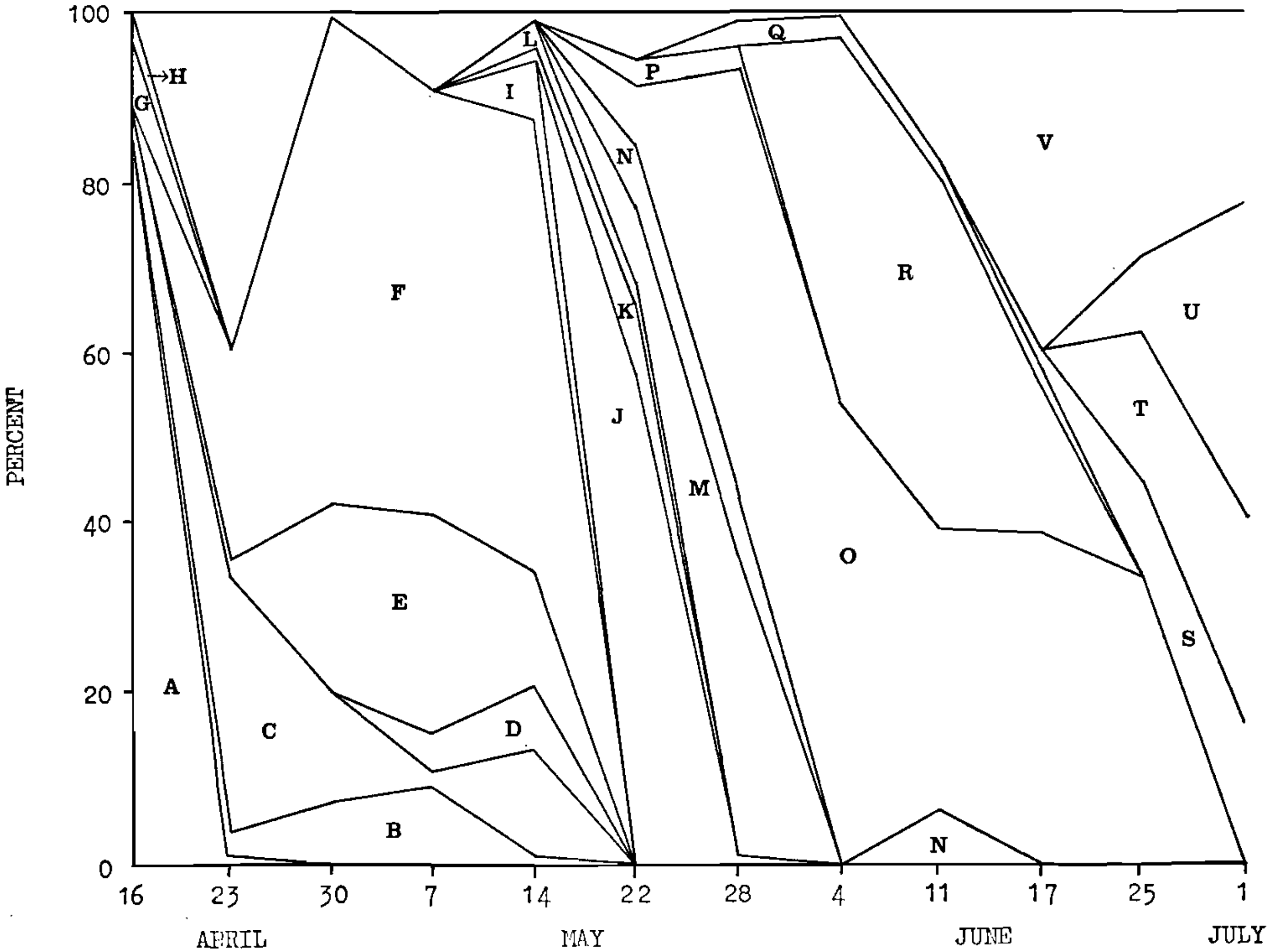
PERCENT
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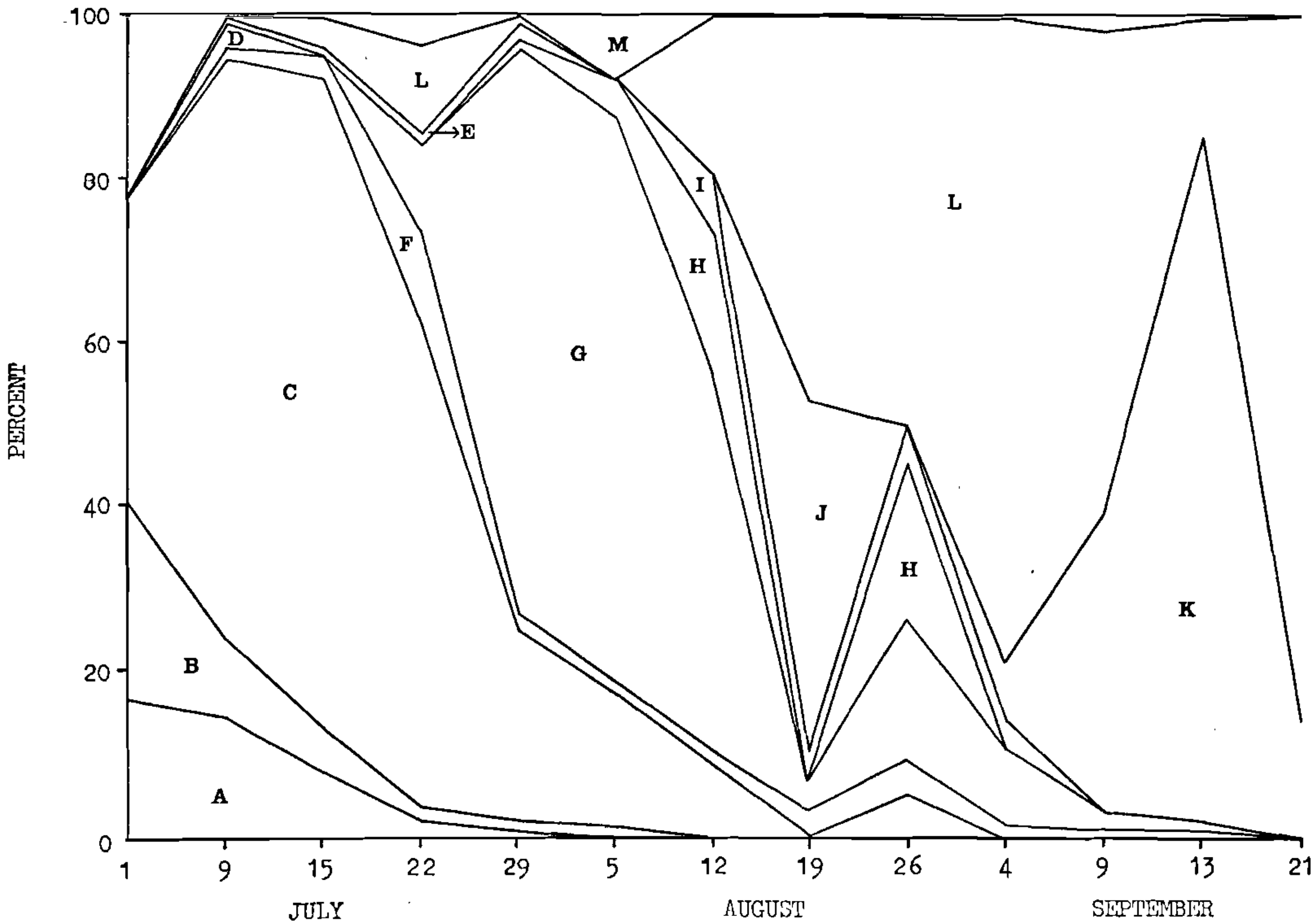
Figure 16 (continued)

LEGEND

A - mustard sp.
B - clover (legume IV)
C - corn
D - sumac sp.
E - birds-foot trefoil
F - red clover
G - buckwheat
H - touch-me-not sp.
I - ragweed sp.
J - sowthistle sp.
K - goldenrod sp.
L - composite sp.
M - unidentified pollens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until late May, with oak accounting for 58.44% of the late April pollen. Pollen from black locust and shagbark hickory was collected from mid to late May. Nannyberry and grape were shrub species providing pollen during May. Pollen from raspberry was only collected for two weeks but accounted for 57.63% of a weekly yield. Red-osier dogwood was collected from mid-May until mid-June, providing a maximum of 35.12% of the weekly pollen samples. False-solomons seal and wild grasses were herbaceous species foraged for pollen in lesser amounts during late May. Legume pollen was collected after late May, providing a maximum of 52.96% of the weekly pollen samples in early June. See Appendix Table 2 for descriptions of those collected. Red clover was less utilized as a pollen source at this site, providing a maximum of only 11.50% of the weekly pollen samples. Birds-foot trefoil pollen was collected in small amounts throughout July. Mustard pollen was collected from late June until August. Corn accounted for up to 79.10% of the weekly pollen samples from late June until late August. Buckwheat provided up to 69.59% of the weekly pollen samples from late July until early September. Touch-me-not pollen was collected from late July throughout August. Composites dominated the September pollen. Those identified as pollen sources were ragweed, sowthistle, and goldenrod.

<u>Site F</u>

The daily percentages of species collected are listed in Table 1. Oak accounted for the majority of the pollen collected each day, with 72.27% being the minimum. Dandelion pollen provided up to 18.65% of the daily collection. Honeysuckle provided a small amount of competition but its effect declined daily from an initial high of 3.02% of the daily

Table 1: The percent of each species of plant foraged for pollen by colonies placed in a commercial apple orchard.

	Apple *Pyrus malus* L.	Oak *Quercus* sp.	Dandelion *Taraxacum officinale* Weber	Honeysuckle *Lonicera* sp.
May 4, 1977	9.44	72.27	15.27	3.02
May 5, 1977	2.03	90.10	7.87	0.00
May 6, 1977	1.70	78.84	18.65	0.80
May 7, 1977	4.82	87.73	6.95	0.46

pollen yield to only 0.46% the final day. Apple was actually a minor pollen source as it provided a maximum of only 9.44% of the daily pollen yield. The total amount of pollen collected increased daily from 11.4071 to 165.2902 grams the final day.

Composite

Figure 17 shows a county-wide composite for all tree, shrub, and herb pollen identified. Tree species provided the predominant pollen collected early in the season. They provided 99.76% of the mid-April weekly pollen samples but were not collected subsequent to late May. Shrubs were utilized as a source of pollen from early May to early July providing a maximum of 55.92% of the weekly pollen samples. Herbaceous species were utilized less through April and May but by mid-June and through the remainder of the season they provided the bulk of the pollen.

Figure 18 shows a county-wide composite of the weekly percentages of wind-pollinated versus insect-pollinated plant species that were foraged for pollen. Wind-pollinated species provided the early pollen sources and were heavily utilized until late May. They also provided up to 63.28% of the weekly pollen samples from late June to mid-August. Insect-pollinated species did not contribute significantly to the very early pollen yields. They did provide up to 50.83% of the weekly pollen samples by late April and 99.65% of those in early June. They then declined to a low of 30.92% in early July but increased by August to provide the bulk of the pollen.

Figure 19 indicates a detailed county-wide composite of the species identified as major pollen sources for the entire blooming season. Each

Figure 17: Plot of the county-wide composite of the weekly percentages for all trees, shrubs, and herbs identified as pollen sources.

LEGEND

Trees —·—·—·—

Shrubs —— ——

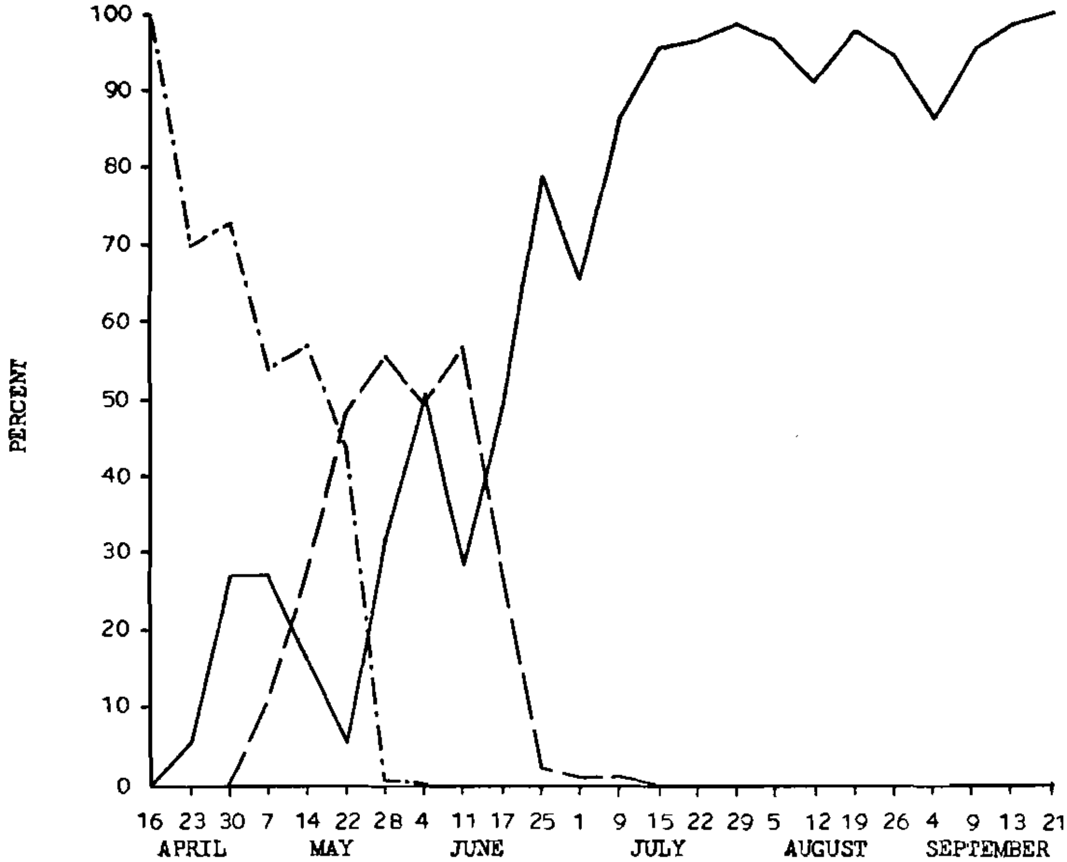
Herbs ————

Figure 18: Plot of the county-wide composite of the weekly percentages of wind-pollinated versus insect-pollinated species foraged for pollen.

LEGEND

Wind-pollinated ————

Insect-pollinated —— ——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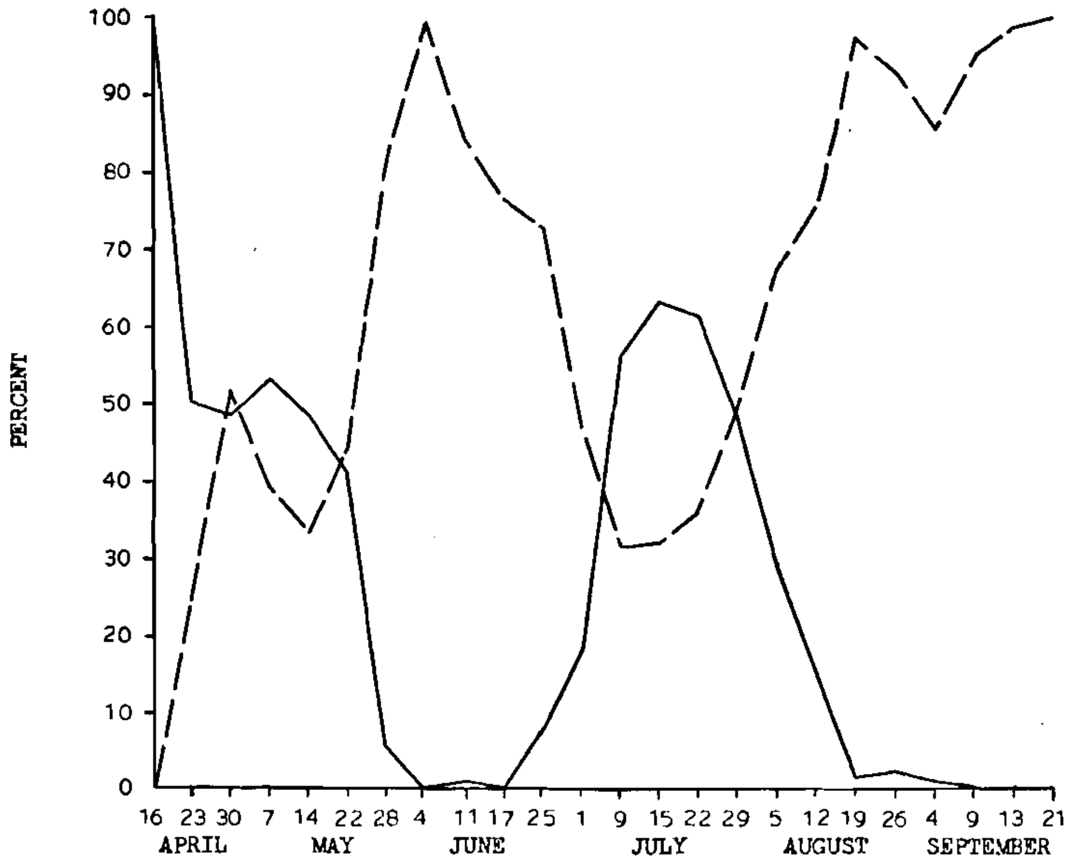
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species is listed as the percent weekly yield. Tree species were the dominant pollen source through late May. Boxelder provided 91.32% of the mid-April weekly pollen samples. Pollen from willow, trembling aspen, and ash also was collected in small amounts during this time. Pollen from apple, cherry, and willow was collected from April to late May. Oak was the dominant pollen source from late April to late May, providing up to 46.90% of the weekly pollen samples. Pollen from black walnut, black locust, and shagbark hickory was collected in late May. Dandelion was the only major herbaceous species identified as a pollen source early in the season. It provided up to 27.36% of the weekly pollen samples from late April to late May. Nannyberry, honeysuckle, poison-ivy, grape, raspberry, red-osier dogwood, gray dogwood, and lilac were all shrub species foraged for pollen from early May until late June. Sumac was the primary shrub species utilized, providing up to 55.17% of the weekly pollen samples. False-solomons seal and wild grasses were lightly foraged for pollen in late May. The legumes were important pollen sources from late May through September. The clovers and sweet clovers provided the bulk of the early legume pollen. A description of those collected is given in Appendix Table 2. Some birdsfoot trefoil pollen was collected from mid-June to mid-July. Red clover was the major legume pollen from mid-July through September. The major pollen source from early July to late August was corn, which provided up to 63.28% of the weekly pollen samples. Buckwheat was utilized as a pollen source in cultivated areas from late July until late August. Touch-me-not pollen was collected in lesser amounts throughout August. Smartweed was a minor pollen source during September. Composite pollen was collected after late June and provided the bulk of the September

Figure 19: Plot of the county-wide composite of the percent weekly yield of the species identified as major pollen sources for the entire blooming season.

LEGEND

A - boxelder
B - willow sp.
C - cherry & apple sp.
D - dandelion
E - ash sp.
F - oak sp.
G - trembling aspen
H - nannyberry
I - honeysuckle sp.
J - poison-ivy
K - black walnut
L - shagbark hickory
M - grape sp.
N - black locust
O - raspberry sp.
P - red-osier dogwood
Q - false-solomons seal
R - clover (legume I)
S - grass sp.
T - gray dogwood
U - lilac
V - sumac sp.
W - clover (legume II)
X - unidentified pollens

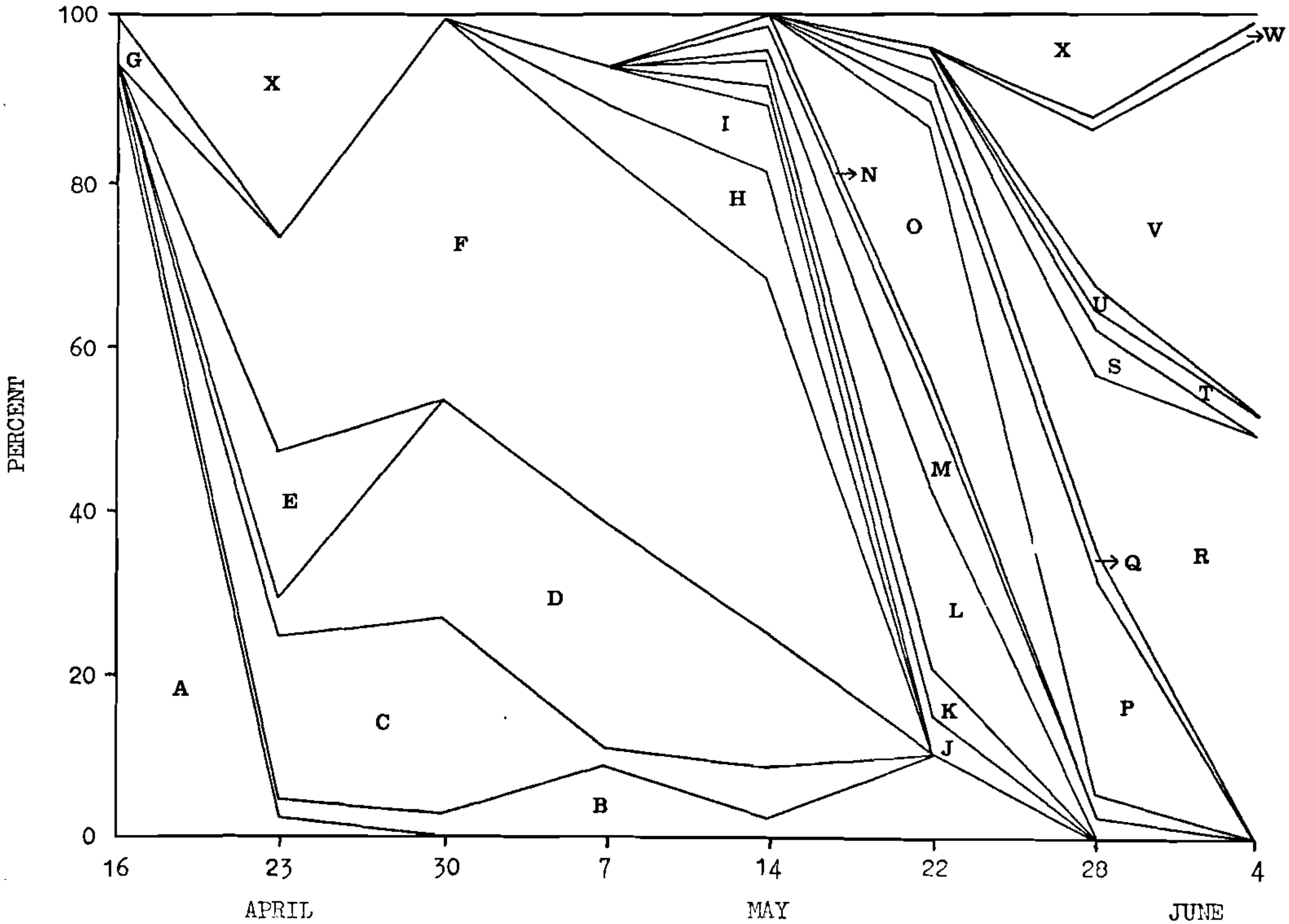

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Figure 19 (continued)

LEGEND

A - clover (legume I)
B - gray dogwood
C - sumac sp.
D - clover (legume II)
E - mustard sp.
F - birds-foot trefoil
G - thistle sp.
H - corn
I - clover (legume III)
J - clover (legume IV)
K - red clover
L - buckwheat
M - composite sp.
N - unidentified pollens

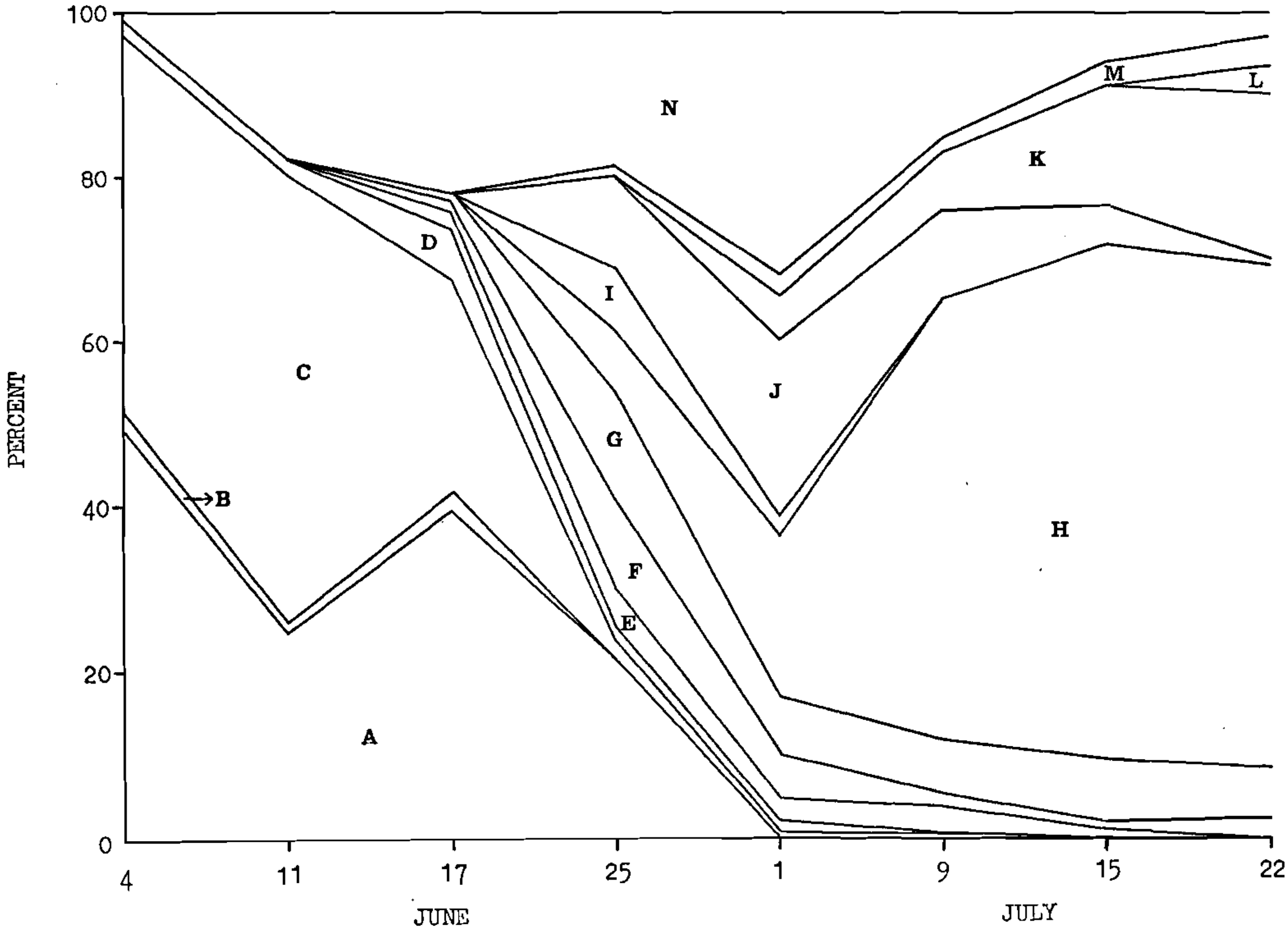

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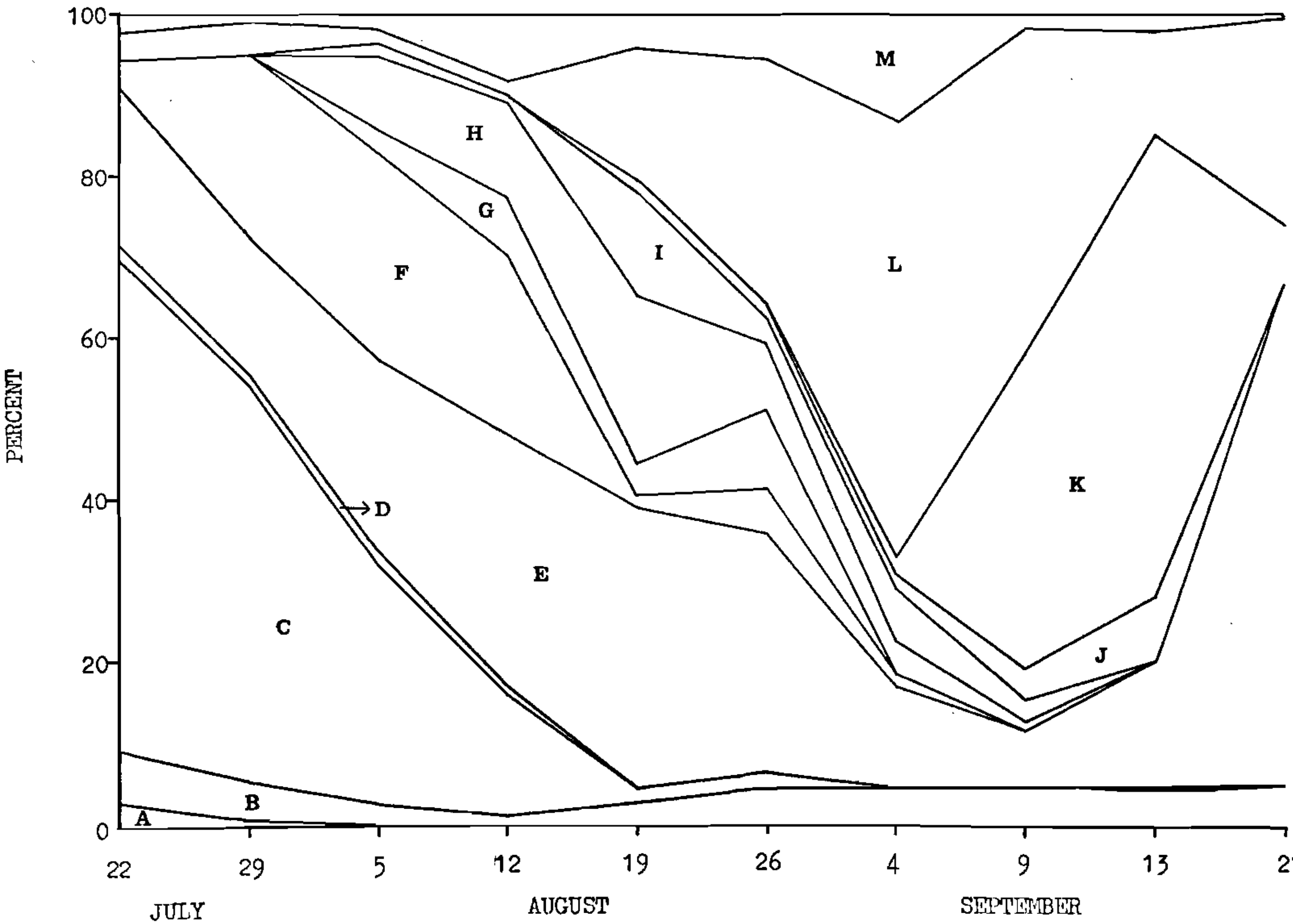
Figure 19 (continued)

LEGEND

A – birds-foot trefoil
B – thistle sp.
C – corn
D – clover (legume IV)
E – red clover
F – buckwheat
G – touch-me-not sp.
H – ragweed sp.
I – sowthistle sp.
J – smartweed sp.
K – goldenrod sp.
L – composite sp.
M – unidentified pollens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pollen. Thistle pollen was collected during this entire period, while pollen from ragweed and sowthistle was collected in August and early September. Goldenrod provided up to 56.90% of the September weekly pollen samples.

A complete list and pollen description of species utilized, including those that totaled less than one percent of the weekly samples, is given in Appendix Table 2.

DISCUSSION

January through May is an important time in the hive calendar since enormous amounts of pollen are necessary for brood rearing. Brood rearing will begin in late January, with the hive relying on pollen stored from the previous season. These stores will quickly become depleted, forcing the bees to seek adequate supplies as soon as the weather permits flight.

In this study tree species were the major pollen source at all sites early in the year. Many of these trees complete their blooming period long before shrub and herbaceous species bloom in abundance and, therefore, provide the earliest source of pollen. These trees were eagerly foraged and provided copious amounts of pollen until late May. Many of these tree species, in particular the very early ones, are considered to be wind-pollinated. This seems to contradict the current philosophy as to pollination vector and flower-form relationships. It is thought that various pollination vectors and flowers have evolved together, resulting in very specialized relationships between them (Meeuse, 1961; Martin, 1975; and Faegri and Van der Pijl, 1966). Also, within the angiosperms, entomophily is thought to be the more primitive condition. Wind-pollinated species that produce copious amounts of pollen and rely on mechanical vectors are considered as more advanced and do not rely on insects for pollination. The bees, however, seem more inclined to forage upon the most abundant and most profitable pollen source in the apiary vicinity, regardless of the pollination vector and flower-form relationships. Doull (1971) and Heinrick (1975, 1976) suggest that bees will forage readily on any profitable source of food that will help maintain the nutritional balance of the colony. Another factor that has apparently received little consideration is the role that bees may play in the cross-pollination of these plant species. Since the bulk of wind-blown pollen travels relatively short distances, this accessory form of pollination may be quite important in expanding the gene pool of a population.

Boxelder, willow, and trembling aspen are all wind-pollinated species found throughout the county that were foraged for pollen in April during this study.

Boxelder was the dominant pollen source during early April. Other Aceraceae species growing within the vicinity of the apiaries were apparently not foraged to any detectable degree. Silver maple (*Acer saccharinum* L.) grew in abundance around Site E but was not identified in the pollen samples. This species is one of the earliest to flower and, therefore, may have been utilized prior to the beginning of this study. However, the maximum daily temperature during April 1 to 6 was only 47 degrees Fahrenheit. Since the bees are unable to sustain flight for long periods at such cool temperatures the importance of this species as a pollen source was probably minimal. Silver maple has been listed as a major pollen source (Olsen, 1975; and Oertel, 1939) and would no doubt assume this role in this area during warmer springs. Sugar maple (*Acer saccharum* Marsh) also grows abundantly within the county but was not identified in the samples. This species blooms somewhat later than the other maples and was apparently ignored in preference to other species blooming at that time.

Willow species provided abundant pollen at all sites except B. They have been listed by Pellett (1976) as a valuable source of spring pollen, which the bees forage in preference to other species. These trees grow along any moist lowland in the county and offer an extremely large amount of pollen.

Trembling aspen tends to grow in small dense stands, providing a locally abundant source of pollen. It does not appear to be a highly desirable pollen source since it was only collected in fairly small amounts at Sites A and E.

Ash pollen was collected in abundance at Site A, with a small amount being collected at Site E. This species is listed as a pollen source by Hodges (1958) and Pellett (1976) but is not included in a list of Wisconsin honey and pollen plants (Oertel, 1939). Bees were observed foraging these trees in great numbers so it appears that they are locally important as a pollen source.

Oak trees provided a large amount of pollen at all sites until late May. Although considered as wind-pollinated, this tree seems highly desirable to the bees since oak pollen was collected in larger amounts than dandelion and fruit tree pollen. Its preference may be due to the large number of these trees within the county and to the extremely large amount of pollen produced by one tree.

Birch and pine are also wind-pollinated species which were utilized in this study as pollen sources early in the spring. Their desirability apparently is quite low, as they provided less than one percent of a weekly yield. Birch trees grew in abundance within the county and produced large amounts of pollen but were ignored in apparent preference to boxelder. Pine pollen was collected only at Site A where there was a pine plantation, and only in very small amounts. Pine species growing around the perimeter of Site E were not foraged to any detectable degree even though these species produce an abundant supply of pollen.

Black walnut and shagbark hickory are wind-pollinated species utilized for pollen in late May. They produced a large amount of pollen which was released over a two to three week period. These trees flowered at an ideal time for bee management, as most early tree species had finished flowering, and herbaceous species were not flowering in large numbers.

The fruit trees provided an excellent source of late April and May pollen. Due to the large number of species of fruit trees found within the county, a considerable amount of this pollen is available for a relatively long period of time. It appears in this study that commercial pollination of cultivated fruit trees may provide limited success in some areas. The overwhelming majority of the pollen collected from an apple orchard in this study was from oak. Futher competition to the pollination effort was supplied by dandelion and honeysuckle. As a result apple actually supplied a small percentage of the daily pollen yield. A question arises whether the amount of apple pollen collected was sufficient to indicate adequate pollination to merit payment for the colonies. The amount of pollen collected by these hives increased daily throughout the experiment, probably the result of the establishment of the colonies in the orchard area and the development of flight patterns as they became familarized with this area. One of the problems associated with cultivated varieties is the necessity of pesticide applications. If pesticides are applied during any period of blossoming, these trees offer a severe threat to the well-being of the colony. Cooperation and proper management will result in mutual benefits for the orchard owner and the beekeeper.

Black locust provided small amounts of pollen during late May at Sites C and E. It is found in small stands and may be more valuable as a nectar source than for pollen, although its blooming period only lasted two weeks.

Dandelion was the only herbaceous species that was an early major pollen source. It provided a generous amount of pollen for four to five weeks at all sample sites. This plant exhibits a cosmopolitan distribution throughout the county, growing in extreme abundance. It seems fortunate for the honeybee that the herbicidal attacks of man on this species are lessons in futility, since it continues to grow and spread.

Late May marks a turning point in the foraging habits of the bees. By this time the tree species are almost spent as pollen sources, while the herbaceous species are not blooming in large numbers. This places the shrub species as the dominant pollen sources well into June.

Honeysuckle, poison-ivy, and nannyberry, blooming in early May, are the first shrub sources of pollen. Honeysuckle is commonly used in hedges and windbreaks while also growing naturally in woody areas. Its pollen was, however, only collected at Sites A and B. Poison-ivy pollen also exhibits such localized utilization, being collected at only Sites C and D. Nannyberry pollen was collected at all sample sites, indicating the species is widespread within the county and quite desirable as a pollen source.

Raspberry, grape, lilac, gray dogwood, and red-osier dogwood are all locally important pollen sources. Each was foraged for very large amounts of pollen at some sites but was apparently ignored at others. However, it was not observed whether this phenomenum is the result of competition by other species or a local deficiency in that particular species.

Sumac was a very important pollen source at all sample sites for four to six weeks, from late May through June. These shrubs were observed throughout the county. This, coupled with their long blooming period, makes them ideal pollen sources. The blooming of these plants was also indicative of another turning point in the foraging habits of the bees. By late May the herbaceous species were present in large numbers and were ready to assume the role as the dominant pollen sources for the remainder of the season.

False-solomons seal was foraged for pollen in small amounts at Sites A and E for a period of two to three weeks in late May. These plants are not normally found in large enough numbers in a given area to supply a high percentage of the colonies needs.

Wild grass pollen was collected at all sites for two to three weeks in late May. It was generally collected in small amounts but contributed a surprisingly high percentage of a weekly yield at Site B. Again, these are principally wind-pollinated species that have attracted a highly adapted pollination vector.

Corn was the major pollen source through mid-summer. It accounted for a very large amount of the weekly yields at all sample sites. The bees appear to abandon their floral relationships in preference to gathering this very abundant pollen. An important problem with regard to this pollen source is the application of pesticides to control the European corn borer (Ostrinia nubilalis) and the corn earworm (Heliothis zea). The honeybees are also quite susceptible to these chemicals, with severe mortality being observed in apiaries after their application. Attempts should therefore be taken to protect the hives when given warning of a pesticide application to this crop.

Mustard pollen was collected at all sites except for Site D. These plants were observed growing in fairly large numbers throughout the county and seem to be synonymous with cultivated areas. In general mustard was foraged for small amounts of pollen although it was an important source at Site E for eight weeks.

The legumes provide an extensive and very important source of pollen from late May throughout the season. Red clover provided the most long-lasting pollen source, being collected from mid-June throughout the season and accounting for a very high percentage of the weekly totals. Hobbs (1957) determined that honeybees in southern Alberta even preferred red clover to alfalfa and other native flowers. Other authors have also reported fairly extensive pollen gathering from this species (Benedek, 1976; Butler, 1941; and Knee and Moeller, 1967). Birds-foot trefoil pollen was collected at all sites except Site D and provided pollen for a considerably long period of time. White clover, alsike clover, and both sweet clovers were all observed growing within the entire county. A problem arises as to their identification as the pollen grains are microscopically identical for all four species. These grains do exhibit color variations which can be used as a tentative method of identification but there is enough variation in the color of each species to make this color identification questionable. These color variations were noticed and represented in this study, with no attempt being made at a species identification. It is sufficient to recognize these species as important pollen sources.

Alfalfa pollen was not identified amoung the samples even though alfalfa grew in great abundance throughout the county and in the case of

Site B even grew right up to the apiary perimeter. Although numerous studies have been completed to assess and develop the honeybee-alfalfa relationship (Bohart, 1954; Gary, Witherell, and Marston, 1973; Hobbs and Lilly, 1955; Loper and Waller, 1970; and Sheesley and Podusha, 1969), it seems to remain as a less desirable pollen source. Limited success has been achieved in selectively breeding honeybees for alfalfa pollination (Mackensen and Nye, 1965, 1968, 1969, and 1970) to enhance seed set in western states. A problem associated with alfalfa cultivation in the LaCrosse area is the agricultural practice of harvesting the crop as its attains full bloom, thus denying it to honeybee access.

Soybeans were also absent from the pollen samples even though there was a large acreage of them around Site C. The relationship between honeybees and soybeans has been studied (Erickson, 1975a, 1975b, 1975c; Jaycox, 1970) with several hundred varieties of soybeans. Some of these varieties do appear quite attractive to the bees while others go apparently unnoticed. With the large acreages of soybeans planted today, there appears to be great potential for increased soybean yields and honey surpluses if the relationship between these attractive soybean varieties and honeybee foraging can be determined and applied to other varieties through genetic engineering.

Buckwheat pollen was collected extensively at Sites D and E throughout late July and August. This cultivated crop appears to be highly desirable to the bees. However, the honey surplus has a strong flavor and dark color which is undesirable to people accustomed to the mild flavor and very light color of clover honey.

Small amounts of touch-me-not pollen were collected at all sites except Site D from late July until September. Also, small amounts of pollen from the wind-pollinated Cyperaceae were collected at Site C in early September. They both appear to have possibilities as pollen sources but are probably neglected in favor of more desirable species.

Smartweed pollen was collected at Site C from late August throughout the remainder of the season. Smartweed is often associated with cultivated lands and tends to grow in rather large numbers if no herbicidal controls are utilized. The soybean field around this location was therefore the probable source of this pollen.

All other species identified as pollen sources after early July were members of the Compositae. Due to the large and diverse nature of this family and the similarities between their pollen grains, species identification was impossible in most cases. However, a few composites were identified as to genera. Thistle was a very important pollen source at Site C and its pollen was also collected in fair amounts at Site D. The grazing land surrounding Site C supported a considerable number of these plants, which bloomed from late June throughout the season. Ragweed pollen was collected at all sites during August, while sowthistle pollen was collected at Sites D and E. Goldenrod pollen was identified at all sites, except Site B where sampling was terminated prior to the bloom of this species. Considering the family as a whole, it is the major source of fall pollen. Sufficient fall pollen is necessary for an adequate wintering adult population and as a stored source of late winter protein for early brood rearing until spring pollens are available.

CONCLUSIONS

A study of the major pollen sources within LaCrosse County, Wisconsin, revealed that these sources are quite varied throughout the blooming season. Some of the more dominant and long-blooming species were oak, dandelion, fruit trees, clovers, sumac, corn, buckwheat, and composites. Other species such as boxelder, ash, raspberry, and red-osier dogwood are utilized for large amounts of pollen but have relatively short blooming periods.

The pollen season can be divided into three distinct categories: the early April to late May tree sources, the late May to mid-June shrubs, and the herbaceous species from mid-June through September.

A considerable amount of the pollen collected came from supposedly wind-pollinated species, raising some question as to the true nature of pollination vector and flower-form relationships. Honeybees are a highly specialized pollination vector but appear to be inclined to forage from any floral source in the apiary vicinity that offers adequate amounts of pollen, rather than rigidly observing floral relationships.

A study of differences in major pollen sources in different apiaries revealed that the same basic species were utilized at all areas sampled. There were, however, significant differences in the amounts of pollen collected from these species. A noticable exception though was buckwheat which is not routinely in cultivation throughout the county and thus was only foraged for pollen in apiaries within flight range of this crop.

A study of plants competitive to commercial apple pollination determined that commercial pollination efforts can be severely affected by competitive plants growing in the orchard vicinity. The bulk of the competition was supplied by oak and dandelion.

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Appendix Table 2: Description of all pollen species identified in bee-gathered pollen from LaCrosse County, Wisconsin, including major unknown species.[1]

Unknowns

Unknown I. Tricolporate, with transverse furrow. Exine rugulate. 28 x 21 microns. Gray corbicular color.

Unknown II. Monocolpate. 42 x 22 microns. Gold to red corbicular color.

Aceraceae (Maple Family)

Box Elder (*Acer Negundo* L.). Tricolpate. Exine tectate, with short irregular swirls. Nearly spheroid. 27 x 25 microns. Tan corbicular color.

Anacardiaceae (Sumac Family)

Poison-Ivy (*Rhus radicans* L.). Tricolporate, with transverse furrow. Exine striate. 30 x 25 microns. Red-orange corbicular color.

Sumac (*Rhus* sp.). Tricolporate, furrows long, polar area small. Transverse furrows rectangular. Exine tectate, subreticulate. 43 x 32 microns. Gold to red corbicular color.

Balsaminaceae (Touch-me-not Family)

Touch-me-not (*Impatiens* sp.). Stephanocolpate. Four short furrows located at corners of rectangular grain. Exine intectate, reticulation coarse. 23 x 29 microns. White corbicular color.

Betulaceae (Birch Family)

White birch (*Betula papyrifera* Marsh.). Triporate. Spherical. Exine indistinctly tectate, psilate. 27 microns. Yellow corbicular color.

Caprifoliaceae (Honeysuckle Family)

Honeysuckle (*Lonicera* sp.). Tricolporate. Exine echinate. 45 microns. Yellow corbicular color.

Nannyberry (*Viburnum lentago* L.). Tricolporate. Furrow long and tapered, transverse furrows narrow to attenuate extensions. Exine thick, with coarse reticulum. 32 x 30 microns. Yellow corbicular color.

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[1] Some pollen descriptions taken from Kapp (1969).

Caryophyllaceae (Pink Family)

Bouncing Bet (Saponaria officinales L.). Periporate. Spheroidal. Grain with 7-8 very large pores. Exine tectate, with coarse, stout columellae. 50 microns. Black corbicular color.

White Campion (Lychnis alba Mill.). Periporate. Spheroidal. Grain with 20-25 pores with 5 micron width. Exine echinate. Black to gray.

Compositae (Composite Family)

Dandelion (Taraxacum officinale Weber). Tricolporate. Spheroidal. Eleven lacunae. 40 microns. Orange corbicular color.

Goldenrod (Solidago sp.). Tricolporate. Spheroidal. Exine thick, with long spines. 21 microns. Yellow corbicular color.

Ragweed (Ambrosia sp.). Tricolporate, with very short furrows. Spines short and broad-based. 22 x 19 microns. Yellow corbicular color.

Sowthistle (Sonchus sp.). Tricolporate. Spheroidal. Lacunae with 10 micron diameter. 38 microns. White corbicular color.

Thistle (Cirsium sp.). Tricolporate. Oblate spheroidal. Furrow narrow, with attenuate ends. Exine thick, spines with an internal cavity. 45 microns. White to purple corbicular color.

Cornaceae (Dogwood Family)

Gray dogwood (Cornus racemosa Lam.). Tricolporate. Exine tectate, psilate. 41 x 30 microns. Yellow corbicular color.

Red-osier dogwood (Cornus stolonifera Michx.). Tricolporate. Exine tectate, psilate. 52 x 38 microns. Green corbicular color.

Cruciferae (Mustard Family)

Mustard (Brassica sp.). Tricolpate. Exine reticulate. Yellow corbicular color.

Cyperaceae (Sedge Family)

I. Periporate. Sub-triangular shape. Large pore at broad end, with 3 more around the periphery. 26 x 22 microns. Black corbicular color.

II. Periporate. Sub-triangular shape. Large pore at broad end, with 3 more around the periphery. 30 x 22 microns. Red-brown corbicular color.

Fabaceae (Bean Family)

Birds-foot trefoil (Lotus corniculatus L.). Tricolporate. Tectate, reticulate. Furrow slender, with large circular pore. 17 x 12 microns. Tan to brown corbicular color.

Black locust (Robinia pseudoacacia L.). Tricolporate. Furrow short, contracted at equator. Exine psilate. 27 x 23 microns. Gray corbicular color.

Legume I. Tricolporate. Tectate, reticulate. Furrow slender, with large circular pore. 29 x 19 microns. Gold corbicular color.

Legume II. Tricolporate. Tectate, reticulate. Furrow slender, with large circular pore. 29 x 19 microns. Green corbicular color.

Legume III. Tricolporate. Tectate, reticulate. Furrow slender, with large circular pore. 29 x 19 microns. Gray corbicular color.

Legume IV. Tricolporate. Tectate, reticulate. Furrow slender, with large circular pore. 29 x 19 microns. Yellow corbicular color.

Red clover (Trifolium pratense L.). Tricolporate, coarsely reticulate. Pore indistinct. 40 x 30 microns. Red-green corbicular color.

Fagaceae (Beech Family)

Oak (Quercus sp.). Tricolpate. Exine verrucate. 30 microns. Yellow corbicular color.

Fumariaceae (Fumitory Family).

Dutchmans breeches (Dicentra Cucullaria (L.) Bernh.). Pericolpate. Apertures large open furrows. Surface appears lobed. Brown corbicular color.

Graminae (Grass Family)

Corn (Zea mays L.). Monoporate. Surface faintly granular. Pore 7 to 15 micron diameter. 100 microns. Gold corbicular color.

I. Monoporate. Granular appearance. 43 microns. Gold corbicular color.

II. Monoporate. Granular appearance. 32 microns. Gold corbicular color.

Juglandaceae (Walnut Family)

Black walnut (Juglans nigra L.). Periporate. Pore number from 9 to 37. Pores aspidate. 35 microns. Yellow corbicular color.

Shagbark hickory (Carya ovata (Mill.) K. Koch). Triporate. Exine psilate. 55 microns. Yellow corbicular color.

Liliaceae (Lily Family)

False-solomons seal (Smilacina racemosa L.). Monocolpate. Exine intectate, per-reticulate. 27 x 34 microns. Red-orange corbicular color.

Trillium (Trillium sp.). Monocolpate. Exine intectate, verrucate. 50 x 45 microns. Gold corbicular color.

Oleaceae (Olive Family)

Ash (Fraxinus sp). Stephanocolpate. Exine finely reticulate. Four short furrows at corners of grain. Orange corbicular color.

Lilac (Syringa vulgaris L.). Tricolpate. Exine thick, with coarse reticulum. 32 microns. Yellow corbicular color.

Pinaceae (Pine Family)

Pine (Pinus sp.). Vesiculate. Exine of body granular. Overall dimensions 83 x 50 microns, body 50 x 40 microns. Yellow corbicular color.

Polygonaceae (Smartweed Family)

Buckwheat (Fagopyrum esculentum Moench.). Tricolporate. Exine reticulate. 50 x 40 microns. Green corbicular color.

Smartweed (Polygonum sp.). Periporate. Exine thick, with muri surrounding numerous lacunae. 60 microns. Light green corbicular color.

Rosaceae (Rose Family)

Apple (Pyrus malus L.). Tricolporate. Exine thin, tectate, faintly striate. 30 microns. Light green corbicular color.

Choke cherry (Prunus virginiana L.). Tricolporate. Exine tectate, strongly striate. 22 x 20 microns. Light green to gray corbicular color.

Raspberry (Rubus sp.). Tricolporate. Exine clavae-verrucate. 22 x 18 microns. Gray corbicular color.

Wild cherry (Prunus sp.). Tricolpate. Exine tectate, strongly striate. 24 x 22 microns. Green corbicular color.

Wild plum (Prunus americana Marsh). Tricolpate. Exine tectate, strongly striate. 38 microns. Light green corbicular color.

Salicaceae (Willow Family)

Trembling aspen (*Populus tremuloides* Michx.). Inaperturate. Exine densely verrucate. 45 microns. Gold corbicular color.

Willow (*Salix* sp.). Tricolpate. Exine reticulum coarsest between furrows, meshes are increasingly fine along furrows and poles. 28 x 24 microns. Yellow corbicular color.

Tiliaceae (Linden Family)

Basswood (*Tilia americana* L.). Tricolporate. Exine finely reticulate. Apertures surrounded by mesexinous thickenings. 40 microns. Yellow corbicular color.

Vitaceae (Grape Family)

Grape (*Vitis* sp.). Tricolporate. Exine psilate. 25 x 21 microns. Yellow corbicular color.